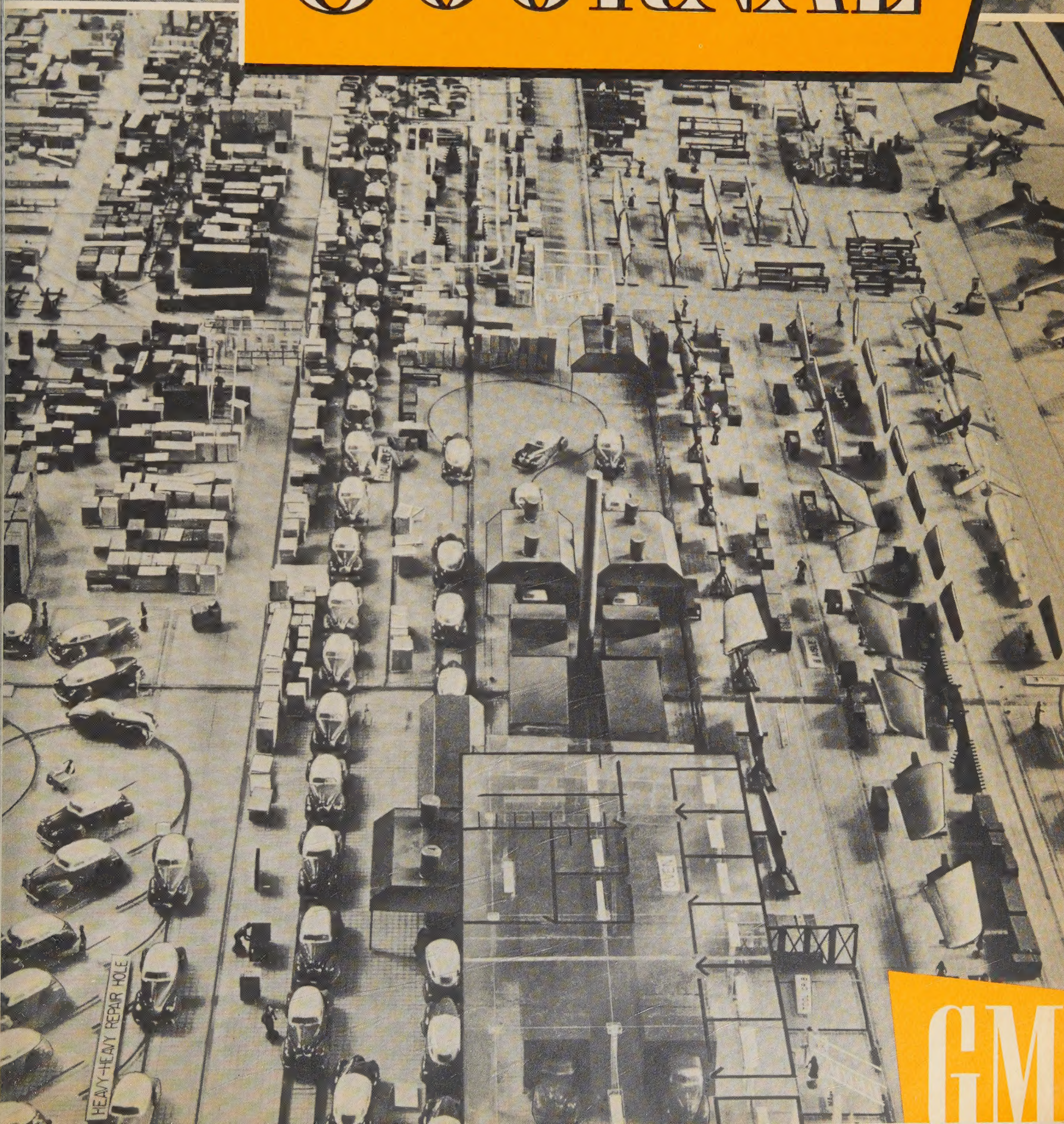
GENERAL MOTORS

Engineering JOURNAL

Vol. 1 June-July 1953 No. 1



GENERAL MOTORS

Engineering JOURNAL

Vol. 1 June-July 1953 No. 1*

Published with the help of General Motors engineers everywhere.

GM ENGINEERING JOURNAL is published every other month* by the Educational Relations Section of the Department of Public Relations, General Motors Corporation, and is intended primarily as a medium for presenting the results of General Motors' research and engineering developments both in the product and production fields.

A. F. JOUPPI, Editor

BETTY EDMAN, Editorial Assistant

E. W. SCANES, Art Director

D. O. BRYSON, Production Manager

Publication office, General Motors Building, 3044 W. Grand Blvd., Detroit 2, Mich.

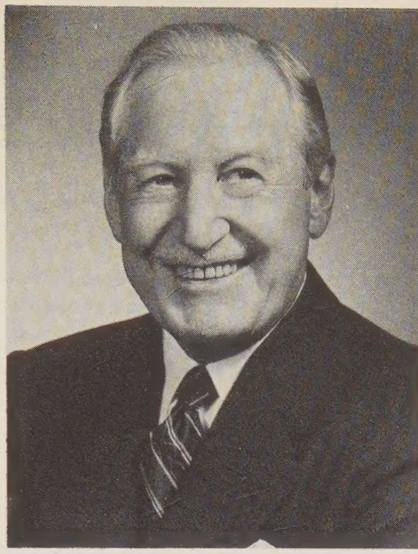
*Vol. 1, No. 1 is an experimental issue. No. 2 will appear in September, allowing time to evaluate reader reaction.

CONTENTS

THE COVER

This year is characterized by a strong dual purpose attitude in General Motors engineering, as illustrated by this model layout. It pictures one of the plant studies made in planning dual purpose operations at the Buick-Oldsmobile-Pontiac Assembly Division's Kansas City plant, where jet fighter bombers will be manufactured alongside GM automobiles. For an account of GM engineers' dual responsibilities see Charles A. Chayne's article, beginning on page 2.

Introducing the GENERAL MOTORS *Engineering* JOURNAL



Harlow H. Curtice

EXCEPT FOR a rich inheritance of accumulated knowledge, the modern engineer would be powerless to cope with the challenges that beset him in his daily work. This accumulated knowledge comes to him in many forms and from many places, principal of which may be his engineering course work in the nation's colleges and universities. The modern engineer's growing heritage of information comes, too, from his own experience and from his industrial colleagues—whether the transfer be through a formal technical paper, or working late at night over a drafting board, or in informal discussion.

Here at General Motors we have a keen appreciation that information is the soul of all the contrivances by which men have bent nature's raw materials into useful products. We know that information demands and begets information, for such is the nature of technical learning. Today's advanced and often complex equipment demands a firm knowledge of engineering fundamentals, but they also demand new horizons of practical technical thinking in order to improve that which the layman already may view as perfect.

We value the new engineer for his grounding in the fundamentals, but we value him also for his vision and his dreams of working with others on the products to come. We try to pass on to him such specialized knowledge as his engineering tasks require and we encourage him to develop new information as he grows in professional stature.

It is from the fund of newly gathered information of General Motors' working engineers and scientists that we seek now to produce the GM ENGINEERING JOURNAL. We hope that it may answer some of the many requests we receive for information on current engineering problems and techniques. We hope, too, that it will be valued as supplementary classroom material by engineering upper classmen and their educators. Further, we know that a practicing engineer's education is never complete; so through the JOURNAL we also are furnishing information to the engineers throughout our organization with the aim that they may find it helpful in their own self-development.

Mindful that the fund of published engineering information already is rich and growing ever better, we pledge ourselves to produce the very best kind of technical literature within the potential of our organization. Some of the information offered we believe to be new and significant; we hope never to stray from that which is old and fundamental.

H. H. Curtice

President,
General Motors Corporation

Responsibilities of General Motors Engineering in 1953

During 1953 General Motors engineering responsibilities are divided between continued development and quality production of goods for civilian use and the production of defense materiel. The challenge of these dual tasks to our engineers will continue as long as a civilian and a defense economy co-exist.

In discharging their responsibilities during 1953, General Motors engineers must keep in mind two places—the battle area and the market place. Both are important. On the fulfillment of the requirements in one depends lives and a share in the preservation of the nation's ideals. In the other, the continued growth in usefulness and productiveness of General Motors and, to a considerable extent, the furtherance of the material effectiveness of the nation's people is at stake.

This year continues a dual-purpose period for the organization as a whole, and particularly for those in engineering positions. General Motors shares with the country the twin challenge of continuing to maintain and advance the standard of living, while at the same time sustaining a military preparedness program.

In discussing the responsibilities which our engineers must carry, it is appropriate to inventory the engineering force we have on hand to do the job, to review some of the recent technological progress in development and production of civilian goods, and to examine the present and projected production of military arms especially where such continues or is projected in conjunction with normal production.

Engineering Force and Its Deployment

General Motors is well known as an organization that operates on a decentralized basis with central coordination and control, wherein each Division is a separate unit headed by a General Manager who directs the operations of his business much as though it were a separate entity. A justification of this mode of operation was made in 1927 by Alfred P. Sloan, Jr., speaking at the GM Proving Ground, at Milford, Michigan. The words of Mr. Sloan, now chairman of the Board of Directors, are as true today as they were then:

We, naturally, think that this is the best scheme of organization or we would not adopt it. Our responsibilities are so great, the necessity of quick action and prompt decision is so great and contributes so much increased efficiency and effectiveness, that it is about the only way a business of the magnitude of General Motors could be conducted. It also has the very great advantage of developing executive ability and initiative on the part of a greater number of individuals.

This concept of decentralization marks every phase of GM's operations, engineering included. Thus, each operating Division has its own chief engineer who directs the product development and under whose authority every drawing is approved before any product is manufactured. Each Division also has a works or manufacturing manager who supervises the technical details of manufacturing.

Each Division maintains its own personnel records, but periodically the Central Office Personnel Staff conducts a survey to determine how many engineers are employed. The most recent of these surveys indicates that the Divisions employed 7,318 graduate engineers in salaried positions as of June 30, 1952. This figure included 1,653 graduates of General Motors Institute. As engineering position descriptions vary somewhat from Division to Division, it is difficult to place a figure on the total number of technical

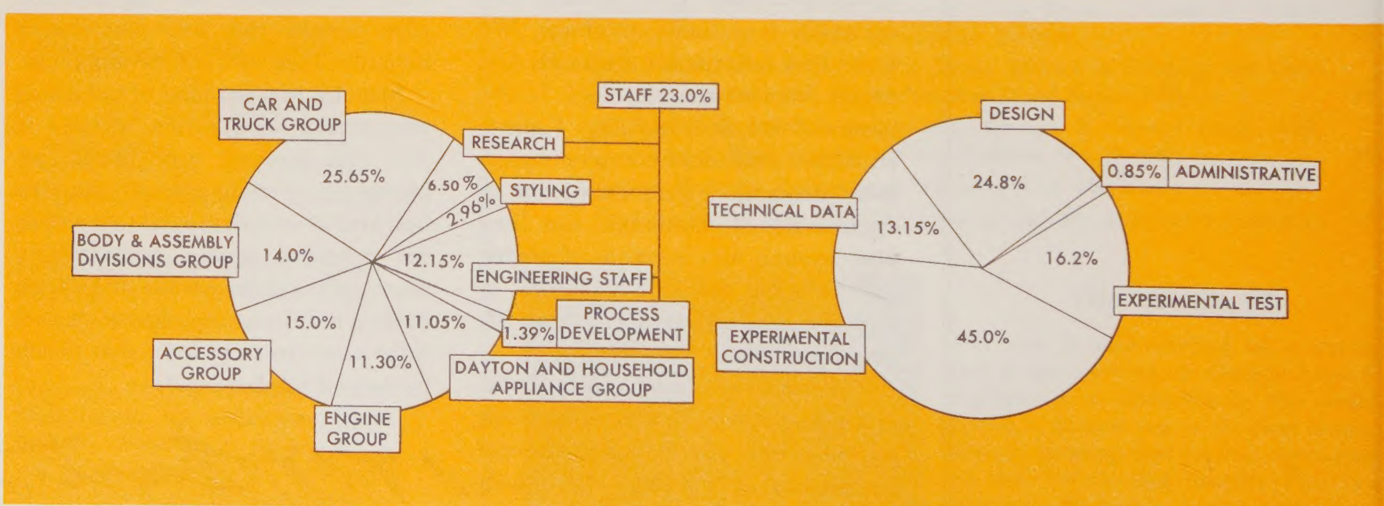
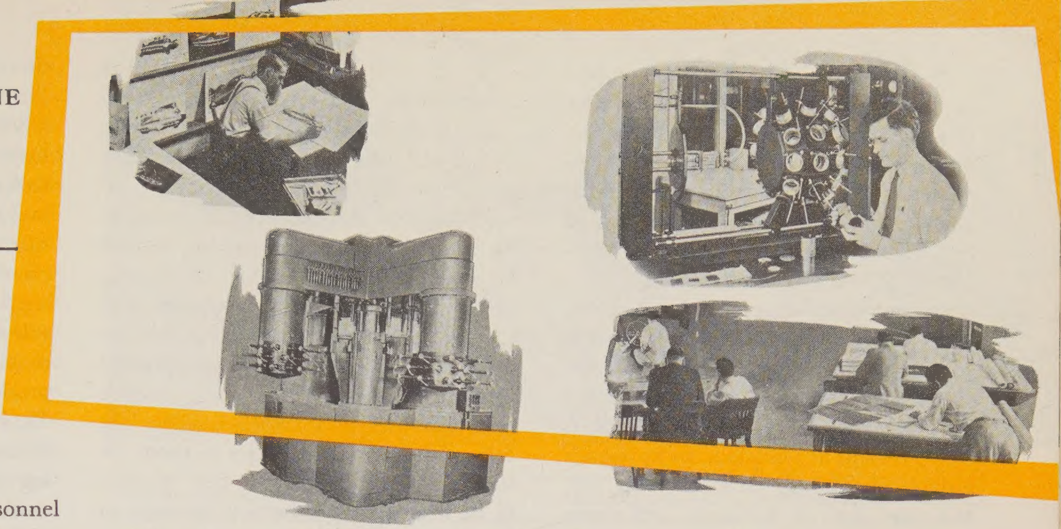


Fig. 1—Distribution of GM product engineering personnel (l.) and the distribution of product engineering personnel assignments in a typical car Division.

By CHARLES A. CHAYNE
Vice President
in charge of
Engineering Staff

Better plowshares and swords, too, is dual challenge



engineering personnel. The Personnel Staff estimates the total at 15,000, including product engineers (Fig. 1), and those in tool, die, and process engineering, and their supervisors.

Since the period before World War II, the total number of engineering personnel has increased rapidly, both in actual numbers and in ratio of engineering personnel to total employment. The number in product engineering positions has more than doubled, and those in tool, die, and process engineering tasks have more than tripled since 1941.

This force of 15,000, then, constitutes the technical talent inventory with which General Motors assumes its current responsibilities. It might be noted that the organization's degree-holding personnel come from more than 950 colleges and universities, which should provide a true cross section of the country's college-trained minds.

The facilities of General Motors Institute are being expanded to meet our growing need for technically trained personnel. At the same time, General Motors continues to seek engineering talent from colleges everywhere. The estimated needs of the Divisions for engineering graduates to meet present requirements and expansion in the months ahead exceed 1,300. About half of these openings are for mechanical engineers, which is quite natural because of the kind of business we are in. However, our requirements for electrical, industrial, metallurgical, and chemical engineers reach sizable proportions, and the individual's opportunities are equally great for all specialties. Additionally, this year the Divisions have made available more than 400 summer positions for engineering students who are looking for an opportunity to obtain some practical experience before they graduate.

The present engineering force represents about four per cent of total employment, and the engineering graduates total about two per hundred of the total employment. Yet, if an established pattern continues, General Motors will look for this small group to fill about 40 per cent of its future executive positions. With the responsibility of engineering goes the opportunity for personal advancement. Today 16 of the 36-member Board of Directors, including the chairman of the Board, have engineering backgrounds. About half of the vice presidents also started their careers as engineers, and along the line there is found in the Divisions a remarkably high percentage of engineers in positions of great responsibility—general managers, works managers, chief engineers, and plant managers.

In summary, the General Motors engineering force is deployed throughout the organization and performs tasks that apply the fundamentals of nearly every branch of engineering that is taught in the nation's classrooms. Many of these men, as they gain experience, will move into positions for which there is no specific university training ground—such as general management responsibilities.

Recent Technological Advances

The mid-century decade, with an accumulation of the knowledge and experience gained from a half century of engineering development in the automobile industry available to its engineers, should bring great strides in new car models, new Diesel equipment, new jet engines, new bombing-navigational equipment, new air-conditioning equipment, and others of the long list of GM products. It also is a period when this word *automation* is gathering fresh meanings as manufacturing processes are becoming more and more automatic. Engineering effort is replacing physical effort everywhere along the line. As a result, our products become even more simple for the user to operate, and hence more valuable and desirable.

The present standards of quality and performance in General Motors products are not the end; they are but the starting place for the future's progress. It is necessary to devise means for making present standard items more economical, both in materials and manpower, through improved manufacturing techniques; and it is also necessary to improve present products. This is as true with military materials as it is for products headed for the proving ground of the market place.

Recent and current showings of the GM Motorama of 1953 and the Parade of Progress have featured many engineering advancements in the motor car, accessory, and household appliance fields which remain the mainstay of the business. Notable public acknowledgement has been given to new engines of higher compression ratio, to improved automatic transmissions, to power steering, to air suspension ride features of new mass transportation vehicles, to recent developments in gas turbine vehicular power plants, to air conditioning of cars, and to current styling developments. The move from the 6-volt to 12-volt electrical systems also has been successfully made in cars which require the higher voltage. Signal seeking radios with features for local favorite station selection also have moved into public acceptance, not only for GM cars but for others as well. The innovations are too numerous to mention here, but those listed suffice to establish the continued program of technological advancement in General Motors.

The public has also devoted attention to the growing GM Technical Center (Fig. 2), located north of Detroit, which now has some of the most modern engineering facilities available to engineers anywhere and, when completed, should help GM maintain its position of technical leadership in the industry.

Development of new processes, tools, and techniques continues. Typical advances recently have been development of the Aldip process whereby base metals are coated with aluminum to make parts more resistant to corrosion; the Surfagage surface smoothness indicator (Fig. 3), and the use of binaural techniques (Fig. 4) to evaluate the effect of car body insulation and padding.

In many instances there is no single GM concept of how an engineering task ought to be done. For example, no standard answer exists to problems so closely related to the development of automobiles as the transfer of power from an engine to the wheels. Typically, General Motors' 1953 car models have three kinds of automatic transmissions, and still another type for military vehicles and other heavy-duty purposes. On the one hand is the picture of General Motors in production turning out highly standardized parts by the millions. On the other is the healthy atmosphere of important differences of opinion on basic technical problems.

In the end, the workaday tests of the buying public are the proving ground for all of GM's products, whether they be farm water pumps or sleek, powerful automobiles. Nothing goes into production until it has been tested thoroughly, however. Before engineering drawings are approved, engineers establish analytical proofs on their work sheets and drawing boards. Then sample models are given thorough testing. In the case of automobiles, the operating Divisions share the facilities of two proving grounds, one at Milford, Michigan, and the other near Phoenix, Arizona.

Every new development is complex. From the production viewpoint, it must be physically and mechanically sound, pleasing from a styling standpoint, and it must be reproducible at an acceptable cost. Thus, there are in GM two general types of engineers. One type conceives new products and improvements; the other visualizes and executes methods for tooling up and getting the new product to fit into mass production patterns so that it may be manufactured economically enough to attract the buying public. The GM Divisions develop both kinds of engineers, and if they should cease to develop them, the productiveness of the organization will wane. There is not a fear of competition, but a wholesome respect for it, along with a willingness to accept its challenge.

Military Requirements

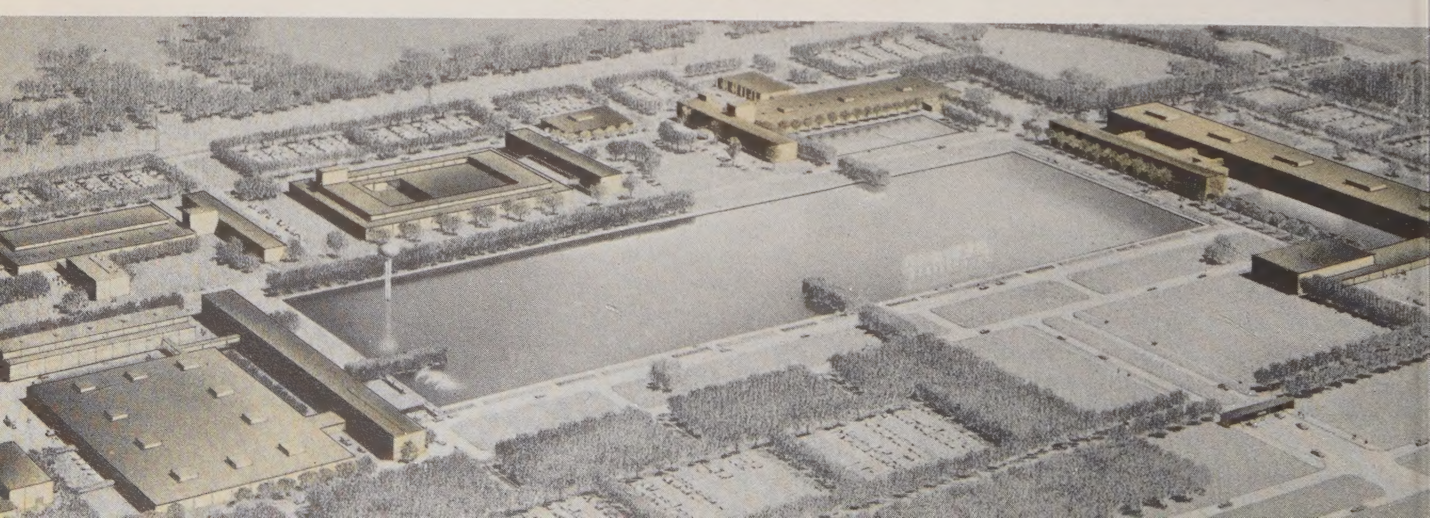
Each time that war or the threat of war has been a reality, the defense effort of our nation has required the adaptation of automotive production capacity to meet the needs of our fighting services. General Motors again has diverted considerable of its engineering and production potential to meet the present military needs, but this time partially on a plan which foresees continued production of military and standard goods side by side and with facilities arranged so that production volume in either field can be scheduled to meet the current need.

When military responsibilities are accepted, they are given top priority by GM. Typical of the Divisions which have diverted considerable of their effort to the defense program is the Fisher Body Division. In addition to its role as a major supplier of tools, dies, jigs, and fixtures for aircraft production, it is building medium tanks at Grand Blanc, Michigan. Another is the Buick-Oldsmobile-Pontiac Assembly Division, which, supported by components and major sub-assemblies from Michigan plants, is making great strides in preparing to produce concurrently cars and F84F Thunderjet aircraft at Kansas City, Kansas. This Division also is constructing a plant at Arlington, Texas, for automobile assembly, but which will be available on short notice for concurrent military aircraft production if the need arises. The Ternstedt Division in Detroit has a program for the production of range finders for several types of tanks, and has contracts for producing instruments and equipment for flight control of aircraft. For each of these operations, the Divisions have made available many of the best technical and management personnel in their respective organizations. These three Divisions comprise the Body and Assembly Divisions Group, and their work is typical of General Motors as a whole.

The AC Spark Plug Division is producing aircraft instruments and gun sights in its Milwaukee, Wisconsin, plant and anti-aircraft fire control equipment at Flint, Michigan. Propellers and actuators are being produced by Allison Division Aeroproducts Plant at Dayton, Ohio. Jet and Turbo-jet engines and tank transmissions are in production at the Allison Division plants in Indianapolis. The Buick Motor Division is producing Sapphire jet engines and tank transmissions at Flint.

Cadillac Motor Car Division has a

Fig. 2—General Motors Technical Center.



plant for the manufacture of tanks and gun motor carriages at Cleveland. Wright aircraft engines are being produced by the Chevrolet Division in its St. Louis and Tonawanda, New York, operations. Some of the Cleveland Diesel Engine Division's engine and accessory production is for military uses. Tank generator sets and parts are in production at the Detroit Diesel Engine Division. The Electro-Motive Division has contracts for the manufacture of military switch engines at La Grange, Illinois. Cargo and personnel vehicles are being delivered from the GMC Truck and Coach Division at Pontiac, Michigan. The Inland Manufacturing Division of Dayton, Ohio, makes tank tracks. The Oldsmobile Division, of Lansing, Michigan, has contracts for rockets and tank guns. The Pontiac Motor Division is making amphibious cargo carriers, rockets, and medium-calibre cannon. This listing, while only part of the picture, is sufficient to indicate that General Motors has assumed a sizable portion of the country's preparedness production burdens. Some contracts are still in a make-ready stage, but the volume of actual output is increasing and could be expanded rapidly if the need developed. As it was during World War II, General Motors is an important producer of military goods as measured in volume of output.

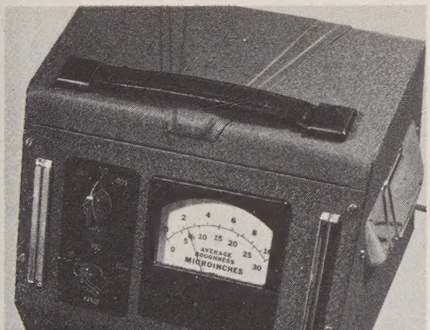


Fig. 3—Surfagage detects surface irregularities as slight as one-millionth inch and provides a uniform and quickly obtained standard of smoothness for all types of finished metal surfaces.

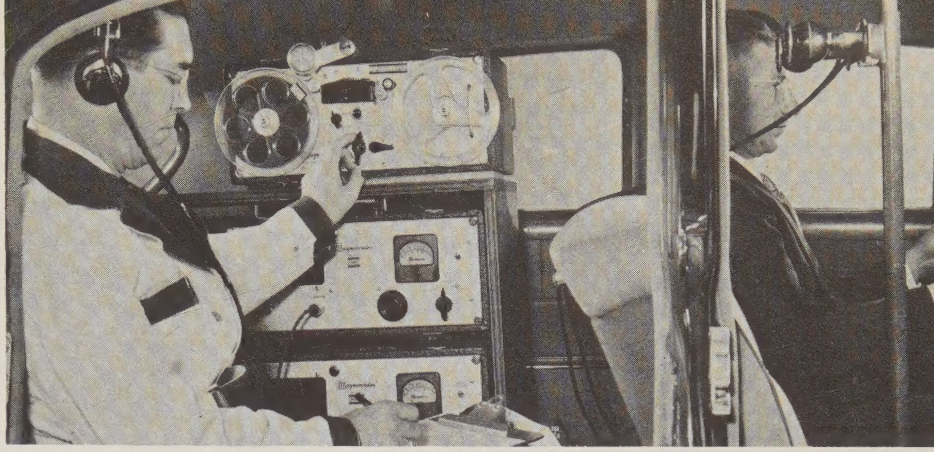


Fig. 4—Fisher Body engineers use the binaural technique in testing a body for sound level. Method uses two microphones and a double sound track. Test runs using different types of padding and insulation are analyzed in the laboratory by simultaneous playback of both sound channels, one channel to each ear.

Most technological advancements which apply to military production must necessarily remain undisclosed, but the variety of the engineering effort which goes into the successful development and manufacture of such advanced devices and machinery requires almost every conceivable kind of engineering knowledge. Fortunately for both General Motors and the nation, the same kinds of talent apply to the engineering and production of tanks and aircraft engines, for example, as to automotive development and production. In many cases, engineers divide their time between civilian and military production problems and, like those at the B-O-P plant in Kansas City, are qualified and prepared to move totally to either field with full effectiveness. That is part of the advantage of the entire dual-purpose plant idea.

The public has accepted this idea with a hopeful attitude. The idea is not new, but it is the first time that it has been put into practice on a considerable scale. Being a peaceful nation, we traditionally wait until a war is upon us and then, with an overwhelming show of productiveness and ingenuity, eventually supply the armed forces with the tools they need to do their job. That was the case both in World War I and World War II. As early as 1944, General Motors went on record endorsing for the nation the concept of continued partial readiness for full war.

The dual-purpose idea attracted nationwide attention in 1951 when Charles E. Wilson, now Secretary of Defense and then President of General Motors, enunciated the idea in an address before the Army Ordnance Association in Cincinnati. Mr. Wilson urged the economic support and development of dual-purpose plants which could be used in these ways: for combined production, for total defense production, or for total civilian production. Thus he foresaw a constant limited defense readiness and a very short transition period from a civilian to a war footing if the need should arise.

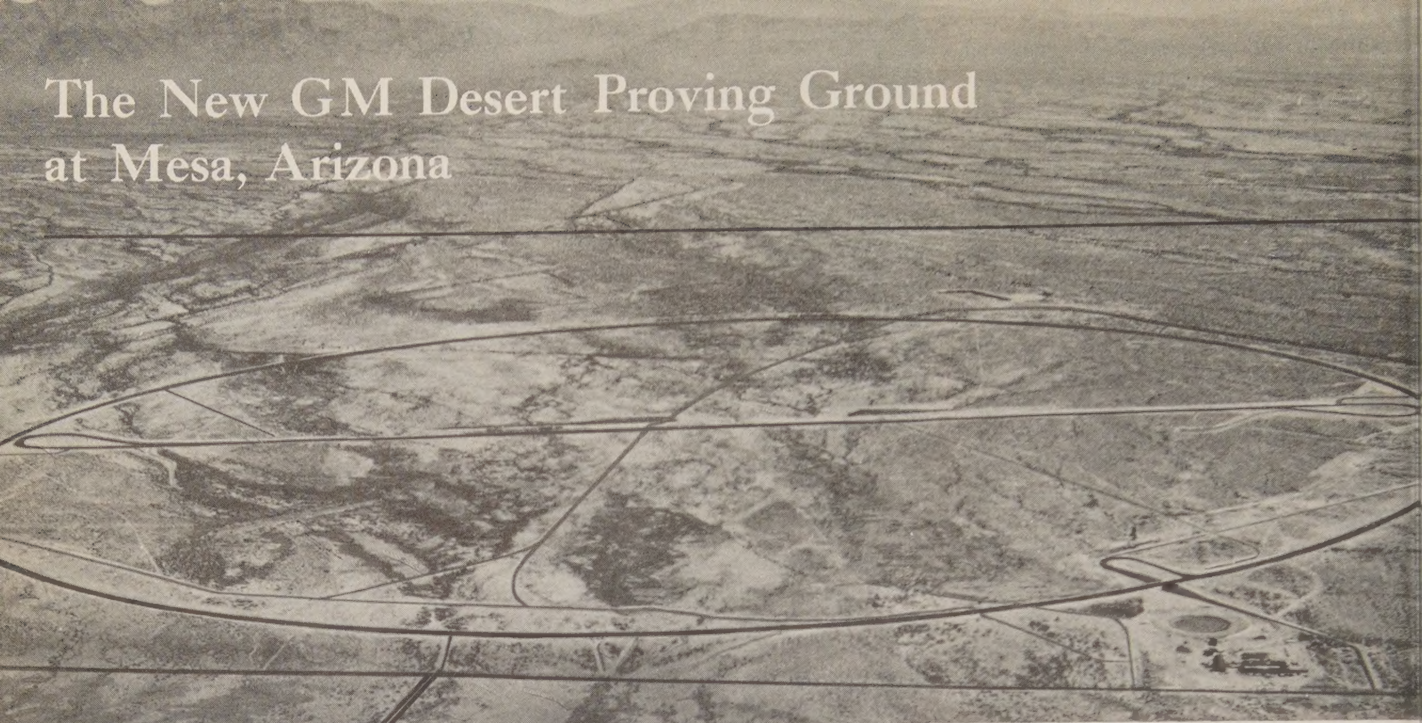
These ideas are coming to fruition in 1953, and may strongly influence our pattern of production for some years to come. The dual-purpose concept is a significant part of today's so-called "guns and butter" economy.

Conclusion

Thus, General Motors shares with the nation the task of maintaining the civilian economy and productiveness at a sound and high level. We want the nation's people to have as many as possible of the good things which make ours the highest living standard in the world. At the same time, we want the nation itself to be sufficiently strong militarily to ward off aggression from unfriendly powers who are reported to be spending most of their national effort to increase their military strength. Then, in spite of everything we do, should a full war finally come, we want to be prepared to move on short notice into full military production and to return sooner to our normal pursuits of producing useful civilian goods at a price which the people can and will pay.

Engineering holds a singularly grave responsibility for the continued successful development of this dual-purpose idea. Whether the individual's task is minute or large, it seems imperative that his decisions be sounder than ever so that the most effectiveness can be derived from the manpower and raw materials we have at hand.

The New GM Desert Proving Ground at Mesa, Arizona



Climatic and topographic advantages of the Phoenix, Arizona, area for testing automobiles are many and General Motors proving operations have been conducted there since the 1930's. The proving ground just completed at nearby Mesa is now in use. Fundamental physical laws have dictated the design of its circular, 120-mph, 5-mile-long test track and the 70-mph-approach-speed turnaround loops for its mile-and-a-quarter straightaway.

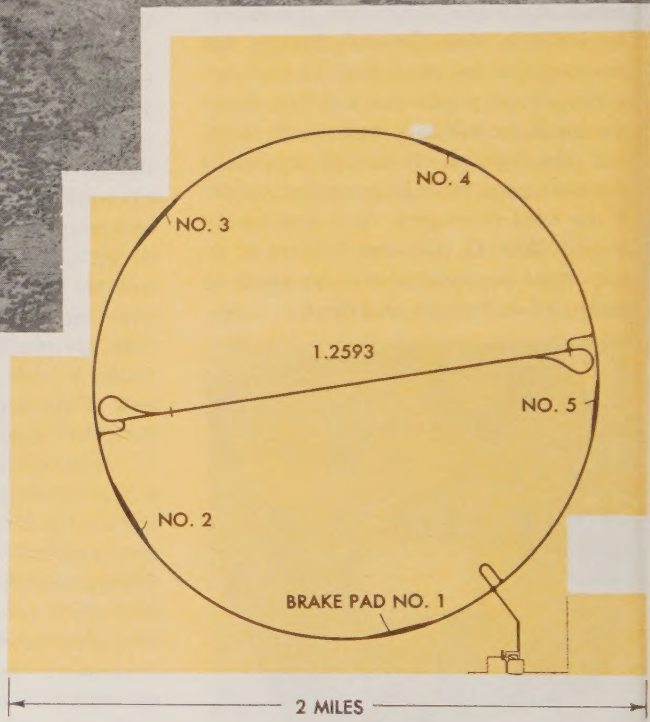


Fig. 1—Desert Proving Ground and its road system.

More than 15 years of General Motors automotive proving activity in the desert and mountainous area surrounding Phoenix, Arizona, has culminated in the development of a proving ground with vast facilities at nearby Mesa. The new facility, completed in February, will serve with the older GM Proving Ground, at Milford, Michigan, for the bulk of the General Motors' automotive testing activities. The site is 34 miles southeast of Phoenix and comprises 2,280 acres (Fig. 1).

The Phoenix area first attracted testing activity because it offers extremes of many physical conditions. For example, usable roads readily accessible from Phoenix range in altitude from 140 to 10,000 feet. The desert heat, dust, high altitude, and mountain roads are valuable in testing automobiles intended for markets in the south and west. (No special models are made for these markets, but standard cars must perform there as efficiently as under more moderate conditions.)

In 1937, testing activities were provided a headquarters at GM's Phoenix Laboratory. This Laboratory found a special place in the test work, especially

By KENNETH A. STONEX
GM Proving Ground
Milford, Michigan

Designing for safe speeds with applied physics

of the Corporation's passenger car Divisions in the southwestern area.

For several years, Arizona public highways proved satisfactory for test work. However, shortly after World War II the traffic volume increased to the point where it became more and more difficult and hazardous to conduct controlled tests. By this time the area had proved itself as a proving ground, and a decision was made to establish a private road system comparable in construction, width, and alignment with first-class Arizona highways. Even though the new proving ground is now in operation, the public highways still find use for certain types of tests, particularly where high altitudes and mountainous grades are required. However, everything which had been done on the flat, straight roads may now be transferred to the new site.

The proving ground at Mesa is so designed that existing facilities may be expanded in coming years. Sufficient land is available to provide all facilities which might be needed in the foreseeable future.

The road system is made of materials commonly used in high-type Arizona highways, and such construction has presented certain design limitations. For example, the usual Arizona highway is constructed by shaping the grade, providing several layers of compacted granular material, and then covering with an oil penetration surface. By choosing basically this type of construction, it was possible to use standard road building equipment available in Arizona. The average Arizona highway is 24 ft. wide and has two lanes. This is the width of the main Desert Proving Ground roads shown in Fig. 1, and they may be widened if future needs require.

From the design standpoint, the most important effect of the decision to adopt conventional Arizona standards was that the side slope of the superelevated curves had to be kept at a maximum value of about 30 per cent. Previous experience at the Milford Proving Ground had indicated that conventional highway construction equipment could be operated on side slopes of about this value, but not much higher, without resorting to unusual accessory means. This limitation of 30 per cent maximum slope was an important factor also in design considerations of the turnaround loops and straightaways constructed inside the circular track. The site was deliberately chosen to provide a nearly flat bed for a circular track layout five miles long. At three points, at the northeast and southwest corners where an otherwise two-mile-square area is broken, the main track comes near the property line. The track radius is approximately 4,200 feet. A shallow watershed from Superstition Mountains crosses the central part roughly from east to west.

A circular track was considered to have many operating advantages over more conventional oval tracks. The superelevation limitation would enable a higher ultimate speed capacity, and design and construction would be much simpler and cheaper because the cross section would be uniform and without transition.

Perhaps the major volume of testing in the area is of cooling systems; this requires protracted operation under constant conditions so that all temperatures are stabilized. Since 1937 this has been done on long, straight, flat stretches of road, and it was felt that a circular track with a long radius would give the best and most nearly comparable test operating conditions which could be found in any closed area of limited dimensions. Similarly, engineering tests in the development of vapor handling characteristics of fuel systems operating in high ambient air temperature, and of car air-conditioning systems require close and consistent control of operating conditions; it was felt that a long circular track would provide optimum test conditions.

The next most important volume of development work is probably long range brake endurance programs; to satisfy this requirement five brakestop pads were spaced equally on the inside edge of the track; freedom from ice and snow and wet roads accelerates these programs significantly.

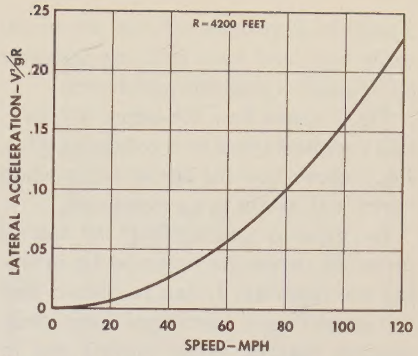


Fig. 2—Relation between lateral acceleration and speed for a 4200 ft. radius, as used at Mesa site.

Acceleration and constant speed fuel economy tests are always essential parts of a development program. To make these possible, an engineering test straightaway with a level grade was built across the diameter of the track to get the greatest possible length.

The necessary operating buildings, garage, office, and living quarters were constructed near the southwest corner of the area adjacent to the best public highway leading to it. An underpass with 14 ft. 6 in. clearance and two 12 ft.-wide lanes gives access to the test track.

Construction of the test track was started early in 1952, and the buildings were begun in the fall of 1952. The track was completed and in operation in June of 1952, and the headquarters operations were transferred from the Phoenix Laboratory to the Desert Proving Ground last February.

Test Track Design

Articles and automobiles traveling in curved paths are subjected to centrifugal forces and lateral, or radial, accelerations which increase with the square of the speed and inversely with the radius.

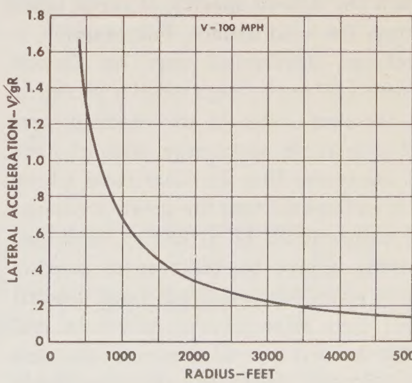


Fig. 3—Relation between lateral acceleration and radius for speed of 100 mph.

Speeds in development work are necessarily high, and large radii are desirable to minimize the centrifugal forces.

Fig. 2 shows how the lateral acceleration rises with speed on a constant radius. Fig. 3 shows how the lateral acceleration varies with radius at a given speed.

In highway engineering the lateral forces on curves are balanced by inclining the roadway. It can be shown that the gravity and centrifugal force components parallel to the surface are in equilibrium when the following equation is satisfied:

$$\text{Tan } A = \frac{V^2}{GR}$$

where
Tan A = Slope of cross section
A = Angle of inclination of cross section
V = Speed in ft./sec.
R = Radius in ft.
G = Acceleration due to gravity = 32.2 ft./sec.^{2}

In standard highway engineering practice the cross section is constructed with a uniform, flat slope, so that there is only one speed at which the lateral forces are in equilibrium; this may be called the design speed, although a friction factor may be included which gives a somewhat higher value of design speed. In an automotive test track where it is necessary to provide equilibrium over a wide range of speeds, a curved cross section is used, with the slope increasing from the inner to the outer edge of the road surface.

In differential calculus the slope of a curve is given by the first derivative of an analytical expression, and in the design of a curved cross section for a test track, an equation can be selected which gives the desired variation in slope, and consequently in equilibrium speed.

In practice, the design is usually based upon the desired spacing of speed lanes across the road surface. For example, a uniform distribution may be desired where a 30 mph design speed is provided at the inner edge of the roadway and 90 mph at the outer edge, with 60 mph at the center line. In other cases where it is anticipated that the greatest volume of traffic would be at low or moderate speeds, it may be desirable to provide more space for low speed lanes toward the inner edge of the curve; in still other cases it may be assumed that most of the traffic would operate at relatively high speeds, and, therefore, more space should be given to high speed traffic.

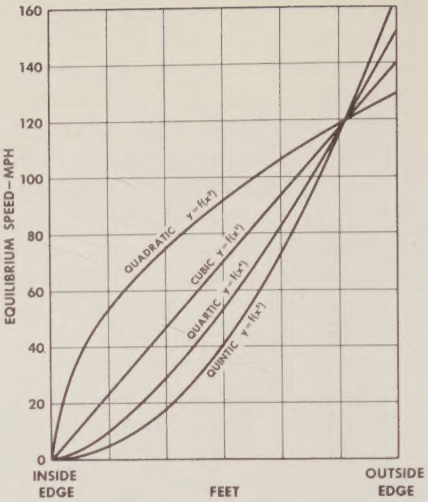


Fig. 4—Equilibrium speed-width relations for four different cross-section equations.

It is possible to select a type of cross section to satisfy any of these requirements, as indicated in Fig. 4. This shows the equilibrium speed across the pavement from the inside to the outside edge derived from designs described by four types of mathematical equations. It may be noted that if the cross section equation is in terms of X^2, the equilibrium speed-distance curve rises fairly sharply and levels off. The speed lanes to cover a range of 20 mph, for example, are much wider at the outer edge of the pavement than at the inner edge. If the equation of the cross section is in X^3, the relationship between speed and distance across the pavement is linear; if the equation is of a power higher than X^3, the lower speed lanes are wider than the higher speed lanes.

Fig. 5 shows typical cross section elevations for curves of these four types with the same equilibrium speed in the outer lane. From this it is evident that equations of higher power give progressively lower elevations at the outer edge. Consequently, the earthwork and cost of construction are considerably less with higher-power equations.

The Desert Proving Ground track was designed with a safety factor by providing equilibrium at the outer edge at speeds far above operating values; a fourth-power cross section was chosen so that only a small width at the outer edge is devoted to speeds above the current operating range. The equation used was $Y = .0000025\,X^4$; the value of Y changes very little for the first several feet, which means that the inner part of the cross section is nearly flat and of little practical value. Consequently, it was in effect discarded and the 24-ft. section from $X = 8$ to $X = 32$ was used.

Fig. 6 shows a plot of the cross section used on the Desert Proving Ground track and the equilibrium speed-distance relation provided. It has a width of 24 ft., a maximum elevation of 2.62 ft, and a maximum slope of .328.

At the inner edge the equilibrium speed is 18 mph, and at the outer edge it is approximately 145. However, at the middle of the outside traffic lane, which is assumed to be 3.5 ft. from the edge of the pavement, the equilibrium speed is 120 mph.

Straightaway Design

An engineering test straightaway should be well over one mile long and probably up to two miles or more if space is available. The Desert Proving Ground layout restricted this length to the diameter of the test track, which is approximately 1.6 miles. Therefore, it was necessary to design the turnaround loops at the end to give the maximum effective length. As shown on the map, these loops are identical as they appear to the driver approaching them.

In constant-speed fuel economy tests, at moderate or high speeds it is essential to make the turn at reasonable speeds to preserve temperature stability as nearly as possible and to permit restabilizing at the test speed early. Thus, the design requirements were to provide a loop with a reasonable design speed, as small as practical for economy of construction and space, and with a maximum superelevation of not much over 30 per cent. A figure of 40 per cent was finally agreed upon as the best compromise of operating requirements and construction difficulty.

Fig. 7 is a design study showing the possible layouts for the turnaround loops. Sketch A shows a 200 ft. radius which would permit operating at 35 mph on the

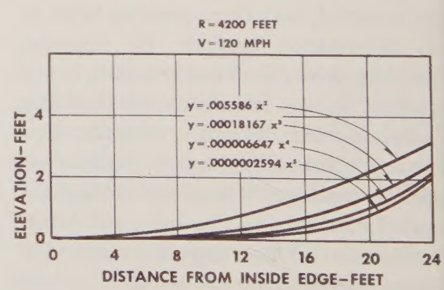


Fig. 5—Cross-section elevations for four different equations with constant radius and speed.

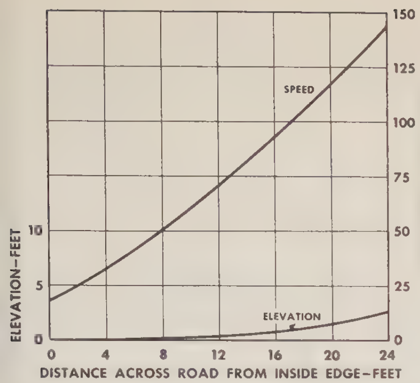


Fig. 6—Cross section and equilibrium speeds for the Desert Proving Ground test track.

turnaround, and Sketch **B** a 400 ft. radius which would have permitted 50 mph. Both provide only minimum clearance from the inner edge of the test track.

Operation on both would be counterclockwise to avoid a traffic crossover. Both designs include a curve to the right with a radius of 800 ft.; this permits an equilibrium speed of 70 mph at a maximum slope of 40 per cent. In both cases the beginning of the 800 ft. radius curve is considered to be the effective end of the straightaway, and the car is braked down after this point.

The end of the straightaway is 1,775 ft. distant from the test track in Sketch **B** and 1,050 ft. away in Sketch **A**. Therefore, the effective length in this phase is 725 ft. greater for the 200 ft. curve of Sketch **A**.

The effective beginning of the straightaway is assumed to be at the end of the turn to the left; in Sketch **B** this is 475 ft. away from the track, and in Sketch **A** it is 250 ft. However, in Sketch **A** the car is actually going only 35 mph. Measurements show that it takes 290 ft. for a recent production Cadillac to accelerate from 35 to 50 mph, so the Cadillac on the curve in Sketch **A** will reach 50 mph at a point 540 ft. away from the track,

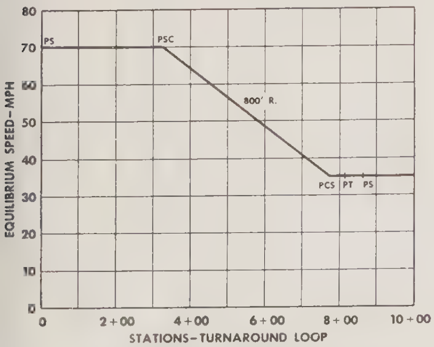


Fig. 8—The equilibrium speed-distance relations from the end of the straightaway into the 200 ft. turnaround loop.

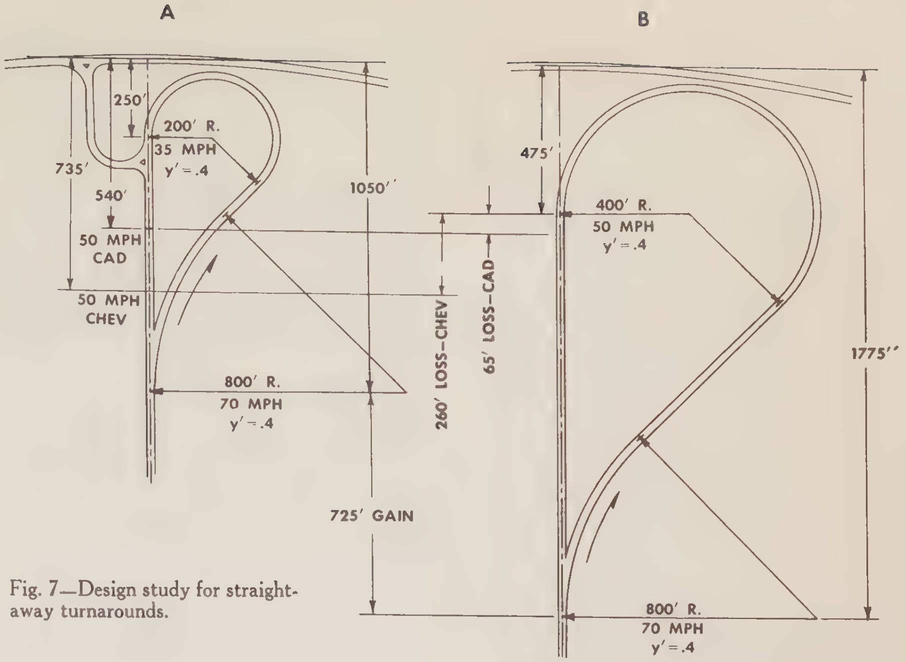


Fig. 7—Design study for straightaway turnarounds.

or 65 ft. beyond the end of the 400 ft. radius curve in Sketch **B**. Thus, the net increase in effective lengths by use of the Sketch **A** layout is 660 ft. at each end. On a late production Chevrolet, the net increase by use of Sketch **A** is 465 ft. at each end.

After this analysis, it was decided to use a radius of 200 ft.

With this radius, the distance between the effective end of the straightaway and the beginning of the 200 ft. curve is so short that the design had to provide for braking down from 70 to 35 mph in the 800 ft. radius curve; it was designed to provide the varying equilibrium speed from the beginning to the end of the curve as shown in Fig. 8, by changing the superelevation cross section continuously to provide for these changes in design speed. The design speed was kept at 70 mph through the transition. Through the circular curve the deceleration rate varies, but the maximum is small so that the maneuver is easy and practical.

Fig. 9 shows the final layout of this curve with the points of change of curvature, the stationing, and profile of the inner and outer edges; this is useful for later reference. The symbols denoting

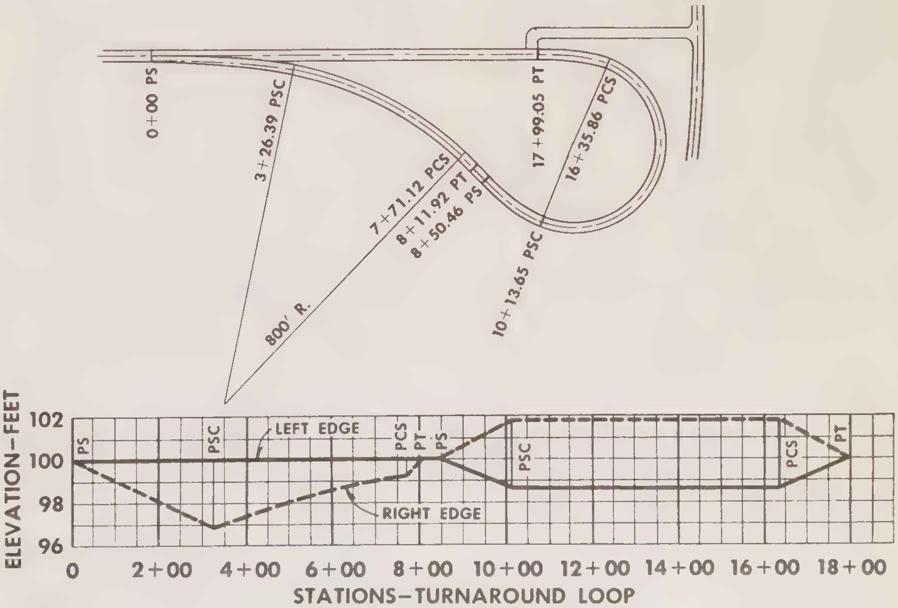


Fig. 9—Layout drawing and inner and outer edge profiles of the turnaround loop.

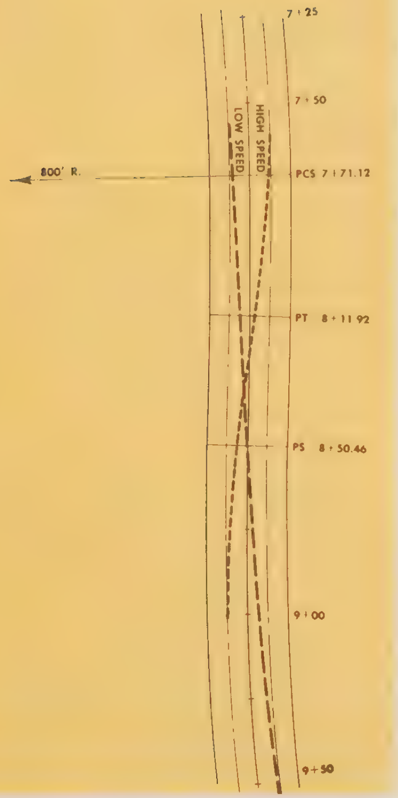


Fig. 10—Paths of the high-speed and low-speed cars traveling from the 800 ft. radius to the 200 ft. radius curve.

points of change in curvature are identified as follows:

- PS—Beginning of a spiral transition into a curve from a straight section
- PSC—Beginning of a circular curve from a spiral
- PCS—Beginning of a spiral out of a circular curve
- PT—Beginning of a straight or tangent section from a curve

Stations are 100 ft. units of distance along the alignment; for example, station 8 + 25 is 825 ft. from the arbitrary origin.

All highway design involving entering curves at high speeds requires a transition element to lead into the superelevated curve. This means that the path must follow some type of spiral with a varying radius, and the superelevation must change in proportion to the centrifugal force as the radius changes. Normally, curves are superelevated by increasing the elevation of the outer edge, relative to the inner.

The transition into the 800 ft. curve was complicated by the fact that the straightaway is a 24 ft. road with passing allowed; to have raised the outer edge would have put a severe bump in the passing lane from the beginning of the straightaway. (This is shown as path AB in Fig. 12.) In this design the outer edge of the superelevated curve was kept level, and the superelevation was increased during the transition section by depressing the inner edge. The roadway was thus warped downward on the right side from the PS to the PSC during the transition to the 800 ft. radius curve, and then twisted back toward the level throughout the curve to provide for the change in design speed. The 200 ft. radius curve was warped in the other direction about the center of the outside lane so that the outer edge, or right side, was raised and the left side depressed. Fig. 9 shows the elevations of the right and left sides of the road throughout the whole turnaround; the solid line represents the left edge of the pavement and the broken line the right edge. Since there is a reversal of curvature, the high speed lane crosses from the left side of the road to the right side during the short tangent section between the two curves.

This tangent section was put in to aid this crossover, as shown in Fig. 10, but it was essential to keep it as short as possible in order to get the maximum effective length of the straightaway. As a result, there is some small irregularity in the elevation in the paths of both the high-speed and the low-speed cars. This irregularity is small, as shown in Fig. 11, and it was considered to be of negligible

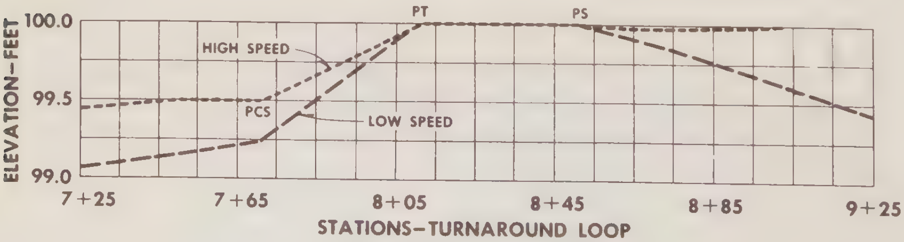


Fig. 11—The profile of the paths followed by the high-speed and low-speed car at the crossover point between the 800 and 200 ft. radius curve.

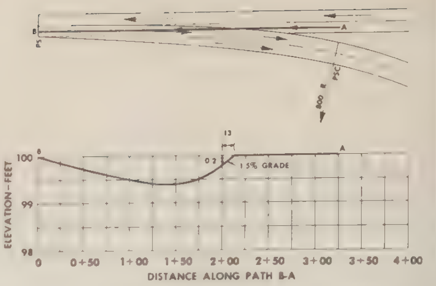


Fig. 12—Layout and profile in the passing lane on the straightaway from a point opposite station 3 + 25.

significance at the relatively low operating speeds.

Fig. 12 shows the wave and its location in the passing lane of the straightaway caused by the superelevation design in the first transition.

This was unavoidable without using a long tapering wedge to widen the straightaway to at least 36 ft. at station 0 + 00, and the effect is not considered especially undesirable because passing maneuvers at this point will be rare. It should be noted that operation is two-way on the straightaway and one-way in the turnarounds; that is, it is one-way all around the loop from about station 3 + 00, and on the beginning of the straightaway from station 18 + 00 up to the point opposite station 3 + 00 (Fig. 9). Thus, there is about 700 ft. at the beginning of the straightaway where the road is straight, 24 ft. wide, and one-way; here, faster cars can pass. From the point opposite station 3 + 00, traffic is two-way and passing is restricted by movements of cars coming the other way. This wave appears in the passing lane only and at the junction of the one-way and two-way portions of the system.

Conclusion

The new GM Desert Proving Ground at Mesa may be expected to record a history of valuable service to automotive engineering advancement. Of special note is that the design has been made safe for those who will conduct millions of miles of tests on its roadways. It is felt that the site selected is excellent in that it has the desired climatic and topographic features to satisfactorily supplement the older GM Proving Ground at Milford. The planning was guided by economy of construction without sacrificing required future services, and the actual design of the roadways was guided by strict application of fundamental physical and mathematical laws.

Emission Spectrographic Analysis in Industry

By DR. ROBERT W. SMITH
AC Spark Plug
Division

A key to the quality and durability of such products as spark plugs is the purity and rather precise relative quantities of materials which go into them. A relatively new analytical tool for determining the presence of certain atoms (and hence, elements) is the spectrograph. Through its use it is possible to determine whether an element is present and in what amount. When the capabilities and limitations of emission spectrography are understood by the several technical services which contribute to a product, this tool can be used effectively and economically at speeds and accuracy levels appropriate to mass production, as well as in more conventional laboratory testing.

Modern spectroscopy detects presence and quantity of elements

THE USE of spectroscopy as a practical tool for the analysis of metallic and non-metallic materials is a relatively recent development. While the potential usefulness of the spectroscope was recognized nearly a hundred years ago, it is only in the last decade that spectrographic analysis has become firmly established in all branches of industry.

The spectrograph was received with misgivings in several quarters. Conservative engineers and production managers feared, possibly from experience, that the introduction of a new scientific instrument might impose on the product arbitrary or unnecessary restrictions, resulting in increased difficulty of manufacturing or testing without compensating improvement in service operation.

Admittedly, there was need for solution of the progressively more acute analytical problem of minimization of error, reduction in cost and increase in speed. But, it was asked, can spectrographic equipment fulfill these requirements, and to what extent? Is it more foolproof than conventional methods, and what are its limits of accuracy? How much developmental work is necessary before, on a given material, rapid, dependable, low cost determinations can be made?

Satisfactory answers to these questions have been provided in a remarkably short time. To appreciate this accomplishment requires some understanding of just what spectroscopy is and of how it can be used to make chemical analyses. No less important is an appreciation of the quality and quantity of preliminary work necessary to the establishment of fast, accurate, reliable, and money-saving procedures.

What Is Spectrographic Analysis?

What the spectrographer really determines is the presence and abundance of specific atoms. An analysis is made on an atomic rather than on a molecular basis and spectrography does not disclose the original state of chemical combination of the elements detected. A typical analytical report merely states that calcium and phosphorus are present in a given sample. The determination does not indicate whether the two elements are present as a calcium phosphate or as a mechanical mixture.

For the purpose of this discussion, the atom may be pictured as consisting of a nucleus surrounded by a number of electrons. The nucleus is composed of neutrons and protons and has an excess positive charge which exerts a force of attraction for electrons. The complete atom has a sufficient number of electrons outside the nucleus to render the whole electrically neutral. The number of extra-nuclear electrons in any atom is equal to the atomic number of the atom, and ranges from 1 for hydrogen to 98 for californium. From the spectrographer's viewpoint only these extra-nuclear electrons are of importance.

The most probable paths in which the electrons travel around the nucleus are called *orbits*. Fig. 1 shows several orbits of hydrogen with some of the possible electron shifts or transitions indicated by the arrows between the orbits. Energy is required to remove an extra-nuclear electron from its inner orbit to an outer orbit because this transition takes place against the force of attraction of the nucleus.

The radii of these orbits, or *energy levels* to which electrons can be excited, differ for each element. Thus, the transitions

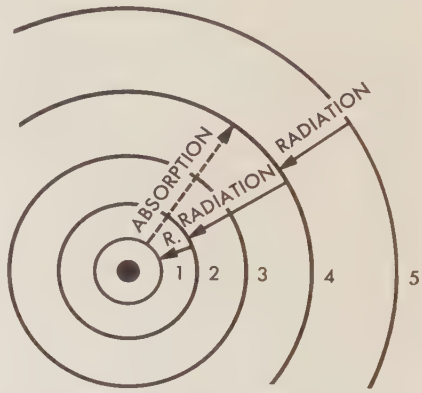


Fig. 1—Bohr's model of the hydrogen atom. The widening circles represent energy states between which electron transitions can occur by the processes of radiation and absorption.

that the electrons can make on the way down from higher to lower energy states differ from element to element. The energy lost by an electron in a downward transition is radiated by the excited atom as light of a specific wave length. For each of the large number of transitions possible, there is radiation of a definite wave length.

The light, which provides clues both to the magnitude of the energy change and to the identity of the emitting atom, can be produced or *excited* by simple means. The relatively low temperature of a Bunsen flame can excite some of the lines of the alkali and alkaline earth metals. This low temperature excitation is employed by the chemist in his familiar flame tests. Using high temperature light sources such as electrical sparks and arcs, many other elements can be induced to emit their characteristic radiations.

Not all elements can be detected by the use of these sources. The ease with which elements can be excited corresponds rather closely to their ability to

form positive ions. This is because both excitation and the formation of positive ions require the transfer of electrons out of their normal paths or orbits around the nucleus. Approximately 70 elements can be detected with the spectroscope, detection being easiest for the metals and most difficult for those exhibiting negative valence in their compounds. The minimum detectable amount of each element varies greatly. The detection of as little as 0.000002 per cent manganese in a sample has been reported. For some elements, such as phosphorus or arsenic, as much as 0.01 per cent may be difficult to detect.

An atom of any element continues to emit or radiate its characteristic spectrum so long as some means of excitation is provided. From a theoretical viewpoint the ultimate sensitivity of the spectrographic method might be one atom. This is true because the processes of energy absorption and light emission could be repeated many times until the total radiation is sufficient to be detected. In actual spectrographic analysis considerably more than one atom is necessary for detection and identification.

Whatever means are chosen to excite a spectrographic sample, the emitted radiation must be analyzed before the spectrographer can determine what elements are present. The optical arrangement of the simple spectroscope shown in Fig. 2 provides a convenient means of separating the radiated energy into its component wave lengths. The optical system of a large commercial spectrograph is little more complex. Radiation from the excitation source passes through a narrow slit, a collimating lens, and a dispersing prism of quartz or glass. The dispersed components of the radiation then strike a photographic plate or film on which a permanent record can be developed. In direct-reading spectrometers the dispersed light is directed into

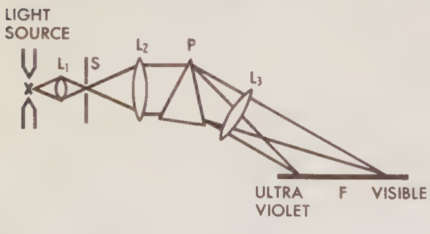


Fig. 2—Simple prism spectroscope. Radiation from the light source is focused on the slit S by the lens L_1. The light collimated by the lens L_2 is dispersed by the prism P and the dispersed components are focused by lens L_3 on the plate or screen at F.

suitably placed phototubes which register intensity by means of amplifiers and associated indicating instruments. Dispersion of the emitted light can also be accomplished by means of the diffraction grating (Fig. 3) which is widely used in commercial spectrographs.

The complexity of an element's spectrum depends upon the number and arrangement of its extra-nuclear electrons. Thus, a light element like sodium, which has only one electron capable of making transitions between energy levels, would be expected to have a simpler spectrum than, for example, manganese, which not only has more extra-nuclear electrons but is so constituted that several electrons can contribute to the process of light emission (Fig. 4).

The invariability of the spectra of the elements makes it possible positively to identify them in any chemical combination or physical condition. The usual procedure is illustrated in Fig. 5, which shows a comparison spectrum of pure copper photographed adjacent to the spectra of two different types of fine silver. It is evident that copper is present in both samples of silver and that the densities of the copper lines are different in all three spectra. This variation in density provides a physical basis for quantitative analysis. If the variation in density depended only upon concentration, the development of spectrographic methods would be greatly simplified. Unfortunately, however, several factors besides concentration affect the observed densities. Important among them are the excitation source characteristics, exposure time, type and adjustment of spectrograph, and photometry. It is the attempt to control all these other factors which has challenged spectroscopists ever since Lockyer carried out the first quantitative spectrographic determinations in 1873.

Modern spectrographic analysis can furnish four different kinds of information, each with its own sphere of application. These four are usually distinguished as (1) qualitative analysis, (2) semi-quantitative analysis, (3) go-no go analysis, and (4) quantitative analysis.

Qualitative Analysis

Strictly qualitative identification of all the constituent elements in a sample is used mainly in trouble shooting. Before specifications can be drawn up to cover the standardization of a material or a process, it is of course necessary to

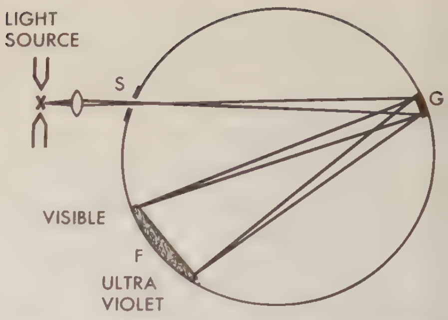


Fig. 3—Typical grating spectroscope. Radiation from the light source is focused on the slit S and impinges on the concave diffraction grating G. The grating disperses the light and focuses the dispersed components on the screen or plate at F. The slit S, the grating G, and the receiver F all lie on the circumference of a circle.

determine the maximum allowable concentrations of objectionable elements; but even before that can be done, it is essential to identify those impurities associated with manufacturing difficulties or with the failure of a product in use.

When trouble occurs in the plant for no apparent reason, spectrographic examinations of the product, of the raw materials, of portions of the equipment, and of satisfactory samples from previous runs can be carried out quickly and easily. Since all detectable elements register their spectra on the photographic film even though no particular one is sought, it is usually possible to spot some outstanding element which can be correlated with the trouble. The presence of elements other than the offending one do not confuse the results, and the sensitivity range is great. This ability to spot unlooked-for elements in a few minutes often pays big dividends when something goes wrong in a costly or high production operation.

A typical instance occurred at AC some time ago in the manufacture of an urgently needed navigational computer for the Air Force. The tiny bearings of certain small gyros began to show excessive wear during running-in tests. The extreme care and cleanliness of the assembly operation, as well as the fact that the gyro was totally enclosed, seemed to eliminate any possibility of contamination from outside. No mechanical or lubricating faults were discovered. Then the spectrograph was pressed into service. A bit of filter paper was rubbed over the oily surfaces of the offending bearing. A dark smudged area appeared which was cut out and burned in an electric arc. In spite of the minuteness of the sample, aluminum, copper, and silicon

Fig. 4—Complexity of optical emission spectra increases with atomic number of the elements. Spectra illustrated are (a) sodium, (b) aluminum, (c) zinc, (d) ferro-manganese, and (e) iron-chromium-cobalt-tungsten alloy.

were all identified along with iron as constituents resident on the faulty bearing. With this clue it was soon discovered that the aluminum alloy gyro housing sections were undergoing fretting corrosion in certain contact areas and that the corrosion products were finding their way into the bearings. A slight redesign completely eliminated the trouble.

In the manufacture of the high-quality ceramic insulator used in AC spark plugs, the spectrograph is often called upon to identify contaminants which cause blisters, stains, cracks, or voids. As these imperfections are usually minute and appear only in the nearly diamond-hard fired insulator, analysis by the usual chemical methods is impractical. Spectrographic analysis is readily carried out by scratching the faulty area with the diamond probe and analyzing the fine particles thus removed. In the majority of cases the analytical results indicate immediately at which step in the complex manufacturing process the contamination has occurred.

While instances such as these are spectacular, in general a purely qualitative analysis is of limited value. Some estimation of amounts is usually demanded (with justification) by the engineer submitting a sample. The meaningful reporting of such analyses is a difficult problem. The spectra of the elements vary from weak to strong and are affected by their modes of chemical combination so that a good guess on an unfamiliar sample is a hazardous venture.

Semi-Quantitative Analysis

A great deal of work is being done to develop semi-quantitative methods which will give a reasonably good approximation of the amounts present in an unfamiliar sample without the extensive standardization required for exact quantitative measurements. Considering all the detectable elements and their possible modes of chemical composition, the achievement of such a universal method will be no mean task. Methods exist now which reliably determine the constituent elements in a completely unknown sample within a factor of two of the true concentrations. This is a great improvement over routine qualitative analysis. (Note that *factor of two* here means that the determination is within half and twice the *true* percentage value. Assume that the true percentage were 1.0 per cent; the *determined* value would be between 0.5 and 2.0 per cent.) It applies well to minute samples since these samples are usually unique and, because they are minute, preclude any analytical procedure other than a single exposure with the spectrograph. Such semi-quantitative analyses are frequently sufficient for the solution of chemical and metallurgical problems without further work. They are also often used for identification of materials, confirmation of samples, and occasionally for determining conformance to specification requirements. At AC they find application in the survey of unusual samples preparatory to chemical analysis, in the sorting of mixed stock, and in the classification of tool steels and ceramic materials. Semi-quantitative analysis of deposits formed on spark plug and engine parts has facilitated understanding of the engine conditions giving rise to such deposits.

Go-No Go Analysis

Spectrographic analysis has opened up the whole field of go-no go determinations, which in wet chemistry is much restricted and is inapplicable to most chemical analysis in industry. This, because of the speed and low cost of such determinations, creates the opportunity of great improvements in quality control. For once a specification is set on a given material, go-no go analyses often are what the engineer is really interested in.

Consider a receiving inspection specification calling for 0.007 per cent maximum of lead in an alloy. It is immaterial to the engineer whether the actual content is 0.001 per cent or 0.005 per cent. Of course, if 0.006 per cent or 0.008 per cent is reported, he wants to know the precision of the determination. This means that a go-no go method is required to have a high degree of precision only at the border line percentages, whether

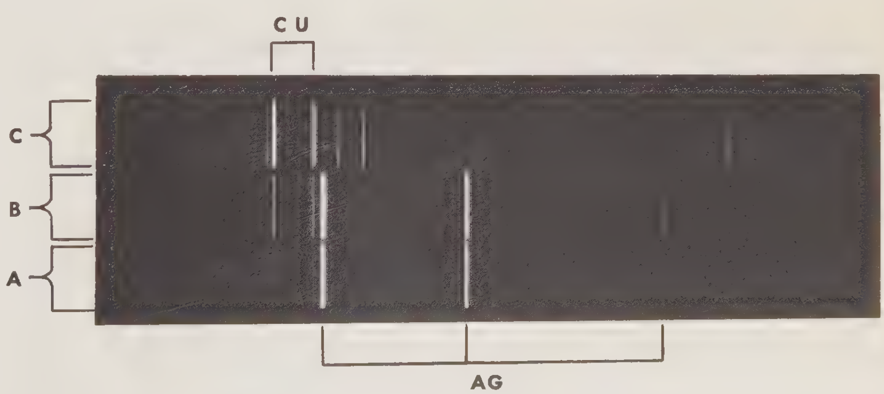


Fig. 5—Variation of copper in samples of fine silver from two different suppliers. A and B are the arc spectra of the two types of silver while C is a pure copper spectrum photographed for comparison. The copper content of sample A is approximately 1 part in a million.

maximum or minimum. The practical advantage of the method derives from the fact that under normal conditions only occasional samples of a given material will have the particular element in question present at the border line percentage. With the great majority of samples, the material can either be reported simply as being to specification or, if the engineer requests, a visual estimate of the percentage can be reported.

Thus, in the above example, if the analyst reported from visual examination of the spectrogram that the lead content was 0.002 per cent, the engineer could be sure that the actual content was not much more than 0.003 per cent or less than 0.001 per cent. If however, visual examination indicated a possible lead content of 0.006 per cent, this sample would then be quantitatively analyzed and the reported result would have the highest possible precision.

A specific example of a go-no go method indicating the possible savings in time and man-hours is the analysis of an aluminum die casting alloy used at AC for some time. This material had originally been analyzed by conventional chemical methods for eight elements, and the spectrographic laboratory also was asked to report the complete analysis of these same elements. A satisfactory procedure was arranged to provide complete quantitative analysis of the alloy. Later, the work load in the laboratory increased so rapidly that it became advisable to re-examine the analytical requirements. It was found that six elements had merely to be kept below certain maximum limits. As long as the concentrations were below the maximum limit, the actual figure was unimportant. With only two elements to determine fully quantitatively, analysis time for the same work load was immediately cut 60 per cent. Only in the case of definite trouble were accurate quantitative determinations required on the six remaining elements.

Quantitative Analysis

In full quantitative analysis the spectrographer performs essentially the same function as the control chemist. Here the concentration of a given element must be determined to the required accuracy over a wide range of compositions. Usually, a good deal of preliminary standardization work is necessary before a speedy, reliable analysis can be made. An ample supply of carefully made and analyzed standard samples must be obtained which overlap the range of expected compositions. Unless the material is one for which commercially available standards can be used, the services of a first class chemical laboratory—and possibly a foundry—are required to furnish standard samples in the same form and metallurgical condition as the unknowns. The spectrographic method is essentially a comparison method and can yield a degree of accuracy no higher than the quality of the standards used.

Here again it should be emphasized that in spectrographic analysis, accuracy depends upon the particular technique employed to a much greater extent than is the case in conventional analytical chemistry. This points up the advisability of close cooperation between engineer and spectrographer before an analytical procedure is decided upon. To ask for greater accuracy than is actually required for adequate control is a needless expense of time and money. A case in point is the determination of barium in AC spark plug electrode wire. Accurate quantitative spectrographic analysis requires about 30 minutes for each sample. However, since the strong spectrum lines of barium happen to be visible to the naked eye, it is possible by direct observation in a spectroscope, to make in 15 seconds an analysis which has a maximum error of perhaps 25 per cent. This rapid visual method has made it possible to check each and every coil of electrode wire on the production floor at a cost so low that it would be uneconomical not to do it, considering the possible losses due to mixed stock or non-uniform wire.

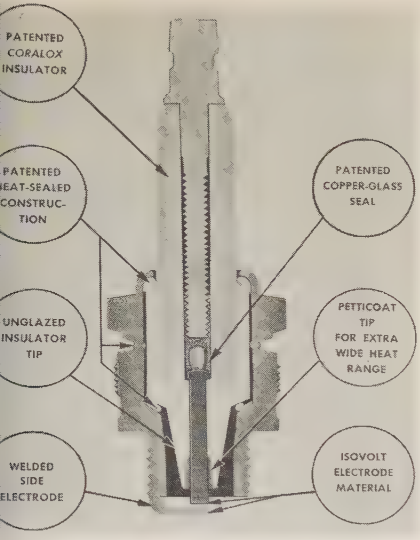
The factor of speed is closely associated with that of economy, and is often predominant in determining the required accuracy. The necessity for rapid analysis is particularly evident in modern metallurgical practice, such as the production of alloy cast irons, steels, or zinc base die casting alloys, by the continuous rather than the batch process. It has been stated as a general rule in this case that the greater the speed with which an analysis can be made, the greater the possibility of accurate control of the foundry operations. Often it is possible to increase the speed of analysis without loss of accuracy.

Spectroscopy at AC

For nearly 25 years AC has contributed to the development of accurate and dependable quantitative spectrographic methods in the firm belief that such methods would lead to improved quality and more efficient production. This development exemplifies industry's eagerness to explore fully new ideas and new instruments which permit higher quality to be built into the product at no increase in cost.

The interest of AC in spectrographic analysis came about as a result of a fundamental investigation of the nature and properties of the electric spark sponsored at the University of Michigan beginning in 1926. Early in the study it was shown that two spark plug gaps of identical geometry made with electrodes taken from the same coil of wire and identical in composition, so far as indicated by routine chemical analysis, might have widely different sparking voltages. It was also found that a given gap required a sparking voltage increasing gradually with continued use. Since it was recognized that changes in the composition of an alloy too small to be detected by routine chemical analysis might affect its electrical properties, the analytical spectrograph was used to survey all the minor constituents of the alloys used. Analysis of alloy electrode wires revealed that the electropositive element magnesium was present principally as small, randomly distributed inclusions, and that this magnesium gradually disappeared from the wire surface during the life of the spark plug. As the magnesium disappeared, the sparking voltage increased. This demonstrated the desirability of having a certain amount of an electropositive substance in the electrode material of the spark plug, and a great deal of work was done to determine the kind and amount of such material to use. From this work came the discovery that a small, controlled amount of barium uniformly alloyed in a suitable nickel alloy results in a spark plug electrode material having a relatively low uniform sparking voltage which remains constant over a long period of use in an engine. This is the widely known and used AC Isovolt alloy used in AC spark plugs of the type shown in Fig. 6.

The development of the Isovolt alloy, involving countless analyses for trace elements, could not have been carried forward without the aid of the speed, sensitivity, and versatility of the spectrograph. Since those early days a continuous effort has been made to realize more



ig. 6—Section through a standard AC automo-ve plug with Isovolt electrodes and Coralox nsulator. Spectrographic analysis contributes im-ortantly to the inspection and control of the ectrodes, the insulator, and the copper-glass eal used in this and many other types of AC park plugs.

ully the potentialities of spectrographic nethods, with the result that a major ortion of the ceramic and metallurgical nalytical work load at AC is carried by ne spectrograph. Several patents cover-ng spectrographic methods have been aken out in a desire to promote their use.

The Future of Spectrographic Analysis

It seems certain that spectrographic nalysis will steadily develop both ver-cally and horizontally. One can expect ew techniques and instrumentation hich will improve speed and reliability nd also decrease the time required for etting up standard procedures. On the ther hand, the method will gradually be xtended to different materials and to ifferent processes. Not only metals, but lso ores, slags, plating solutions, lubri-ating oils, even gaseous mixtures, will be nalyzed as a matter of routine plant peration.

Probably the most striking develop-nents in the vertical direction will be n the field of direct reading spectrom-ters. The dream of spectrographers for ears has been the direct observation and ecording of spectra without the necessity r time-consuming and more or less ncertain photographic manipulations. ntil recently there were no radiation-nsitive devices to compare with the hotographic emulsion, but the develop-nent of photo-multiplier tubes has hanged this situation, and direct inten-ty measurements on spectrum lines are now an accomplished fact. There is no doubt that in the future routine continuous control analysis will be measured in seconds rather than minutes or hours. The availability of such instruments will have an increasingly important influence on the organization and the production methods of metallurgical plants.

For the near future the direct reading instrument will be most used only where large numbers of repetitive analyses are being made on selected alloys. Unlike the photographic plate it does not record all radiations entering its optical system, but only previously selected lines which are used in the analysis. Conventional spectrographic equipment and procedures will be required by laboratories doing work of any variety or setting up procedures for eventual transfer to direct reading instruments. Also, the high initial costs of present day direct reading spectrometers will limit the number of possible applications.

Another vertical development will almost certainly be the discovery and correlation of more fundamental principles of spectral excitation. At the present time no one source will excite the spectra of all the elements, and in actual practice there are about as many sources as there are spectrographers. There seems no good reason why the number of useful sources should be more than four or five, or why the conditions for reproducible excitation should not be determined once the material to be analyzed is known. Fundamental studies of this kind were started only a few years ago and will eventually remove much of the empiricism from spectrographic analysis.

The horizontal expansion will probably take in new materials and also wide composition ranges, so far considered to be beyond the ken of the spectrograph. One application of interest to metallurgists is the work now being done on foundry slags and the flames from Bessemer converters. Quantitative analysis of the slag components gives a continuous check on cupola operation, and direct observation of the changing spectrum of the converter flame enables the operator to follow precisely the course of the various reactions taking place during the blow. At least one large foundry has spectrographic equipment right on the charging floor for continuous control slag analysis.

Another important development is in the analysis of Diesel engine lubricating oils for wear metals and harmful contaminants. An increasing number of railroads are finding that spectrographic analysis of their Diesel engine oil at regular intervals enables them to evaluate engine condition and to make repairs before serious trouble develops. It also enables scheduling expensive overhauls on a basis of indicated need rather than at regular time intervals.

In considering the future usefulness of spectrographic analysis, it is appropriate to repeat in substance the opinion expressed by the chief metallurgist of one of the nation's largest copper producers. Consider the analytical background of an ordinary commercial alloy such as brass. One would first think of a simple, routine conformance analysis for copper, tin, lead, and iron. It must be noted, however, that two component metals have been separately mined, milled, smelted, and refined before alloying together, and that in the direct line of metal processing over 150 elemental determinations have been made. While not directly a part of the analysis of brass, the determinations have been made, and cumulatively, they have established the present high degree of brass purity. The picture can conceivably be still further enlarged to include analysis performed on waste products, by-products, reverts, and fluxes which would increase the total by about 50 per cent, to well over 200 determinations. This figure multiplied by all metals and all alloys represents a tremendous annual expenditure in man-hours and dollars, and constitutes a most promising field for developmental spectrographic effort.

Bibliography

1. Smith, D., "Analysis by Excited Atoms," *Interchemical Review* (Autumn 1945), pp 67-74.
2. Ruehle, A., "Reproducibility in Spectrochemical Analysis," *Bull. A.S.T.M.*, No. 109 (March 1941), p. 33.
3. Ashcraft, E., "Accuracy Requirements in Analysis," *Bull. A.S.T.M.*, No. 109 (March 1941), p. 32.
4. Harvey, C., "Spectrochemical Procedures" (Glendale, California, Applied Research Laboratories, 1950).
5. Ahrens, L., "Spectrochemical Analysis" (Cambridge, Mass., Addison-Wesley Press, 1950).
6. Sawyer, R., "Experimental Spectroscopy" (New York, Prentice Hall, 1944).

Balancing and Vibration Problems Related to Rotating Electrical Machinery

To the non-technical user of electrical machinery and to the engineer alike, an absence of vibration is a mark of quality. Analytical and empirical data coincide in the finding that static and dynamic unbalance in rotors is the major cause of vibration in electric motors. The two kinds of data have served to establish a useful simplified equation and a simple nomograph for determining the maximum vibration to be expected from a given amount of rotor unbalance.

VIBRATION and its causes, effects, and elimination are not a new problem. However, vibration is becoming increasingly more objectionable to the consuming public because of noise and fatigue resulting from use of the machine. It is natural for buyers to associate a quiet, vibration-free machine with the quality which comes from skilled craftsmanship and precision manufacturing.

In addition to these general qualities resulting in consumer acceptance, vibration is undesirable because it causes excessive wear, high bearing loads, difficult lubrication, and may cause fatigue failure of some member of a machine. The accuracy of precision instruments, tools, and machinery is impaired by excessive vibration. Vibration-free machines can be built without bulk and weight and thus more economically generally.

This paper is concerned primarily with the vibration of electric motors. It has been found that rotor unbalance is by far the greatest factor causing vibration in fractional horsepower models. Excessive bearing clearance, rough ball bearings, magnetic hum, uneven rotor air gap, and excessive shaft end play are other minor factors which may cause vibration of electric motors.

Rotor unbalance causes vibration because the mass center of the rotor does not coincide with the axis of rotation. One of the laws of mechanics states that a free body in rotation rotates about an axis through its center of gravity. However, if the body is confined by bearings and forced to rotate about an axis not coincident with an axis through its center of gravity, centrifugal forces are set up. These centrifugal forces act outward from the axis of rotation and rotate with it, tending to displace the bearings in a circular path. These oscillations are vibrations caused by rotor unbalance.

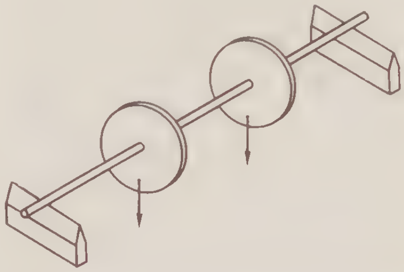


Fig. 1—An assembly which is statically unbalanced mounted on knife edges.

Conditions of Unbalance

A condition of unbalance, either static or dynamic, exists when the center of gravity of a rotor does not lie on the rotational axis.

Balancing may be defined as the redistribution of mass so that the center of gravity is made to lie on the axis of rotation.

Static Unbalance

An assembly mounted on knife edges is shown in Fig. 1. The black spots indicate weights or heavy spots which cause the assembly to rotate until they come to rest at the bottom position. This assembly can be put in static balance by adding weights to one or both discs until the assembly does not tend to rotate from any position in which it is placed on the knife edges.

It is apparent then that static balance may be obtained by the addition of one balancing weight correctly placed. Two or more forces at the same or different angles may be resolved into components and added algebraically to obtain the magnitude and placement of the balancing weight.

Dynamic Unbalance

Dynamic unbalance may occur even when a rotating body is statically in balance, but a body in dynamic balance is always in static balance. Further, it is necessary to add a correction weight in each of two planes to obtain dynamic balance, rather than in one plane as with static unbalance.

An assembly in static balance is shown in Fig. 2. Although the center of gravity lies on the rotational axis, the ends of the shaft each tend to describe a circle when the rotor is spinning. The shaft generates conical surfaces with the apex of each somewhere inside the assembly.

In rotation these unbalances cause centrifugal forces which act in opposite directions and tend to rotate the whole assembly about some point on the rotational axis.

This point on the rotational axis is the common apex of the cones generated by the revolving shaft ends and is theoretically free of vibration. In an electric motor there are other disturbances in addition to rotor unbalance, and this point does usually have some vibratory motion, but it is at a minimum. This position on the shaft is called a node and is very important because of the use of its non-vibratory characteristic in practically all dynamic balancing techniques.

If the assembly has only one disc which is out of balance, the movement of the shaft is as shown in Fig. 3. In this case, the unbalancing moment causes the nodal point to be shifted away from the plane containing the unbalance, and not

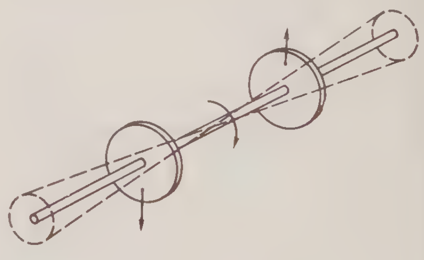


Fig. 2—A system in static balance but dynamically unbalanced showing how the shaft is displaced when the system is in rotation.

By O. LEROY PURTEE
Delco
Products
Division

How analytical findings refined by experiment led to a valid nomograph

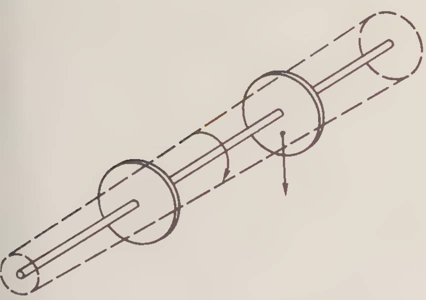


Fig. 3—Unbalance in one plane showing how the shaft is displaced when the system is in rotation.

only causes vibration at the bearing nearest the unbalance, but also at the far bearing. However, the magnitude of the shaft displacement (vibration) is less at the far bearing than at the bearing nearest the unbalancing moment.

In this particular case, simply putting the unbalanced disc in static balance restores dynamic balance to the system. Note, however, that putting the assembly in static balance by addition of a weight to the disc on the left would not produce dynamic balance in the assembly.

Stated mathematically, two conditions must be met if dynamic balance is to be obtained: (1) an algebraic summation of forces in any direction must equal zero, and (2) an algebraic summation of moments about any point must equal zero. Satisfying the first condition results in static balance only.

Relating Rotor Unbalance to Vibration

Correlation of Experimental Data

Vibration data were taken on 100 motors of each of three models. The models used were typical high production Delco motors. One motor model tested was a split phase, 1/6 hp, 1,725 rpm, 115 volt, sleeve-bearing motor with die cast rotor designed for oil burner applications. Another model used was a capacitor-start, 1/3 hp, 1,725 rpm, 115 volt, sleeve-bearing, general purpose motor with welded copper-conductor bar rotor. The third model used was a washing machine unit, a 1/3 hp, 1,725 rpm, 115 volt, split-phase, ball bearing motor.

The following procedure was used for each model of motor:

Ten rotors were accurately unbalanced to 1/16, ⅛, and ¼ oz-in. at each of three angles: 0, 90, and 180 mechanical degrees between the unbalances in the two balancing planes. The tenth rotor was balanced to about 1/200 oz-in. Horizontal vibration amplitude readings were taken at both motor bearings with all ten rotors in all ten motors for an equivalent of 100 motors. This gave a total of ten vibration amplitude readings for each point on the motor for the ten conditions of unbalance investigated.

The equipment and test set up used is shown in Fig. 4.

The amplitude readings were then treated statistically to determine the equation of the line which best fitted the data taken. Other statistical calculations were made as an objective measure of the relationship between vibration amplitude and rotor unbalance. These measures of correlation by statistical analysis are summarized in Table I and the factors explained below:

(a) The coefficient of correlation r indicates how closely related one variable is to another. This coefficient is a pure number ranging from zero to unity. A coefficient of correlation of zero indicates no relationship between the two variables; a coefficient of unity indicates perfect correlation.

(b) The coefficient of determination r^2 indicates what part of the variation in

Fig. 4—Equipment and test set-up used in making vibration measurements. Motor rests on fixed sponge rubber to isolate it from the vibrometer. The equipment rests on a spring-suspended heavy steel table.

Position	Unbalance Displacement	r	r^2	Sy
MODEL A				
Shaft	0°	.990	.980	.00016
End	90°	.967	.935	.000234
	180°	.979	.959	.000115
Opposite	0°	.995	.990	.000087
Shaft	90°	.988	.975	.0001182
End	180°	.985	.970	.0000955
MODEL B				
Shaft	0°	.996	.992	.000076
End	90°	.996	.992	.000092
	180°	.992	.984	.000140
Opposite	0°	.996	.992	.000075
Shaft	90°	.995	.990	.000091
End	180°	.993	.986	.000115
MODEL C				
Shaft	0°	.997	.994	.000086
End	90°	.889	.790	.000421
	180°	.993	.986	.000090
Opposite	0°	.984	.968	.000189
Shaft	90°	.990	.980	.000130
End	180°	.985	.970	.000121

Table I—Summary of statistical analyses on correlation of rotor unbalance and motor vibration amplitude for three models of fractional hp motors.

one of the variables is explained by the other variable. For perfect correlation, the coefficient of determination is unity.

(c) The standard error of estimate *Sy* represents the probable error in estimating one variable from the other. It is controlled largely by how well the data fit the regression curve (line-of-best-fit, Fig. 5). If all data exactly fitted the line, *Sy* would be zero. In the analyses presented here, *Sy* is given in inches of vibration amplitude.

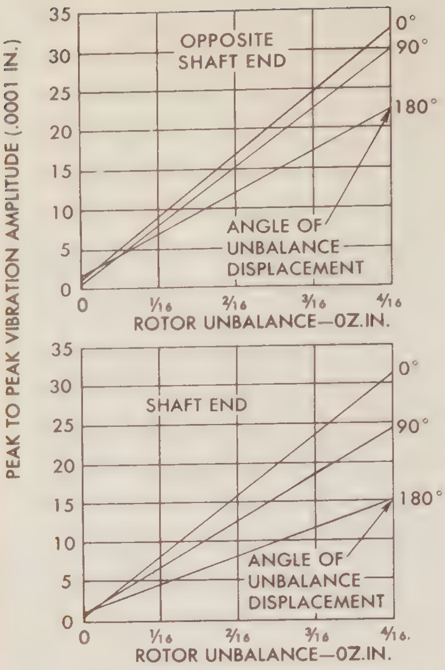


Fig. 5—Statistical line-of-best-fit for observed data measured at both bearings on 100 motors of same model.

An Equation for Estimating Vibration from Unbalance

The derivation of an equation for calculating the amplitude of vibration caused by unbalance is presented below. It was first presented by W. I. Senger[1] as a method for determining the displacement of a rotor shaft in flexible bearings caused by unbalance.

Fig. 6 shows a rotor which has an unbalance, w, in the left end. The addition of this weight causes the center of gravity to shift from cg_0 to cg', and if unconfined, the rotor will rotate about axes X'' and Z''. The distance A is the amount the rotor shaft will be displaced in rotation because of the unbalance weight w.

The sum of e and aJ is A, the quantities to be determined.

A valuable approximate solution for the quantity A may be stated quite simply. The equation, which is derived in the Appendix, is as follows:

$$A = \frac{wr}{8W} + \frac{wrhJ}{8g(I_x - I_z)} \qquad (1)$$

where A = peak-to-peak amplitude in ins.:
w = weight of the unbalance in oz.
W = weight of the motor in lbs.
r = distance to the unbalance from the rotational axis in ins.
h = distance from the center of gravity of the rotor to the unbalance weight parallel to the rotational axis in ins.
J = distance from the center of gravity of the motor to the point of vibration measurement in ins. (generally the bearing midpoint)
g = constant of gravity in ins./sec.^{2}
I_x = moment of inertia of motor about an axis perpendicular to the rotational axis through the center of gravity in lb.-ins.-sec.^{2}
I_z = moment of inertia of the rotor about its rotational axis in lb.-ins.-sec.^{2}

This equation has been found to determine the vibration amplitude at the bearing nearest the unbalance weight. Obviously the unbalance also affects the vibration at the other bearing.

Equation (1) may be adapted to calculating the vibration amplitude at the bearing farthest from the unbalance, or for calculating vibration amplitude at both bearings when there is unbalance in each of both balancing planes (two balancing planes are required for dynamic balance). Fig. 7 shows a rotor which has the balancing planes at the two ends of the rotor cylinder.

The adaptation of equation (1) to permit calculation of peak-to-peak amplitudes for both bearings and for unbalances in the two balancing planes at either 0 or 180 degrees displacement with respect to each other yields the following equations:

for **OSE**, 0 degrees displacement,

$$A = \frac{wr_2}{8W} + \frac{wr_1h_1J_1}{8g(I_x - I_z)} + \frac{wr_2}{8W} - \frac{wr_2h_2J_1}{8g(I_x - I_z)} \qquad (2)$$

for **OSE**, 180 degrees displacement,

$$A = \frac{wr_1}{8W} + \frac{wr_1h_1J_1}{8g(I_x - I_z)} - \frac{wr_2}{8W} + \frac{wr_2h_2J_1}{8g(I_x - I_z)} \qquad (3)$$

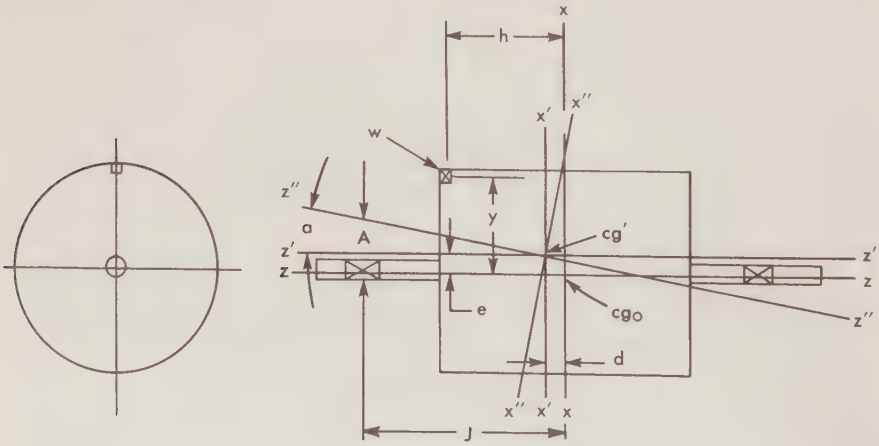


Fig. 6—Diagram of rotor with displaced rotational axis caused by unbalance weight in rotor.

[1]Senger, W. I., "Specifying Dynamic Balance," *Machine Design*, November-December 1944 and January-February 1945.

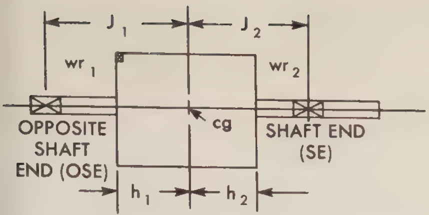


Fig. 7—The quantities used in the estimating equations.

for SE, 0 degrees displacement,

$$A=\frac{wr_1}{8W}-\frac{wr_1h_1J_2}{8g(I_x-I_z)}+\frac{wr_2}{8W}+\frac{wr_2h_2J_2}{8g(I_x-I_z)} \quad (4)$$

for SE, 180 degrees displacement,

$$A=-\frac{wr_1}{8W}+\frac{wr_1h_1J_2}{8g(I_x-I_z)}+\frac{wr_2}{8W}+\frac{wr_2h_2J_2}{8g(I_x-I_z)} \quad (5)$$

It may be noted that h_1 is always used with wr_1 and h_2 with wr_2; also that J_1 is used for the OSE and J_2 for the SE. These equations are valid for calculating vibration amplitudes at any position on the motor. In case the amplitude at the middle of the motor is desired, J becomes equal to zero and the amplitude is the sum or the difference of the static quantities, depending on the angle of unbalance displacement.

The calculation of amplitude at the bearings with an angle of unbalance displacement of 90 degrees is the square root of the sum of the squares of the amplitude of vibration caused by the two unbalances for each end.

A comparison of amplitudes as calculated by the above equations and as measured with a commercial vibrometer is shown in Table II. Significantly, the observed values agree very closely with the calculated values, but are slightly higher.

Condition of Unbalance		Calculated (.001 in.)	Observed (.001 in.)
1/16 oz-in.	OSE 0°	0.79	0.93
	SE	0.74	0.82
1/8 oz-in.	OSE 0°	1.59	1.75
	SE	1.57	1.60
1/4 oz-in.	OSE 0°	3.16	3.42
	SE	2.96	3.16
1/16 oz-in.	OSE 180°	0.50	0.65
	SE	0.37	0.45
1/8 oz-in.	OSE 180°	0.99	1.16
	SE	0.74	0.82
1/4 oz-in.	OSE 180°	1.99	2.22
	SE	1.47	1.57

Table II—Calculated and observed amplitudes for motor model A. Vibrometer used was of the optical-mechanical type.

Based on this and many other data it was found practical to further simplify equation (1) so that vibration amplitude can be estimated from motor weight and unbalance by making suitable allowance for the difference between calculated and observed values as well as the difference between equation (1) and the equation based on motor weight and unbalance. The final estimating equation now in use at Delco Products and a nomograph of the equation are shown as Table III.

Summary

As a result of this investigation it was found that rotor unbalance causes about 93 to 99 per cent of the vibration amplitude of fractional horsepower motors. It was found that vibration amplitude can be estimated with good accuracy from certain rotor and motor physical characteristics. From additional experimental data taken on Delco Products Division motors, an empirical equation was developed which enables the motor design engineer to estimate vibration amplitude from rotor unbalance and motor weight. The empirical equation gives more accurate results and is much easier to use than the derived equation. This new tool has provided a sound engineering specification for balance at Delco Products Division.

Appendix

Derivation of Vibration Equation (1)

Let Iz be the moment of inertia of the rotor about the Z axis before the unbalance weight w is added. After adding the weight the moments of inertia about the Z and X axes, respectively, become:

$$Iz_w=+Iz\frac{wr^2}{g} \quad (6)$$

$$Ix_w=Ix+\frac{wh^2}{g} \quad (7)$$

where

r = distance to the unbalance from the rotational axis in ins.

h = distance from the center of gravity of the rotor to the unbalance weight parallel to the rotational axis in ins.

g = constant of gravity in ins./sec.^{2}

Since the X and Z axes were principal axes and the Z axis was an axis of symmetry before adding the weight, the product of inertia was zero. However, after adding the weight the product of inertia becomes:

$$Ix_wz_w=\frac{wrh}{g} \quad (8)$$

Moments of inertia about the translated axes X' and Z', from the transfer theorem become:

$$Ix'_w=Ix_w-d^2\ \frac{W+w}{g} \quad (9)$$

(Note: The term w will not satisfy the units of the equation at this point, but dividing equation (24) by 16 oz. satisfies the units of equation (1).)

$$Iz'_w=Iz_w-e^2\ \frac{W+w}{g} \quad (10)$$

where W is the rotor weight in lbs. and d and e are as defined in equations (13) and (14), below. However, in practical application W becomes the motor weight, as in equation (1).

By definition, the product of inertia about the translated axes is:

$$Ix'_wz'_w=\int x'z'\ dM. \quad (11)$$

Substituting from Fig. 6 for x' and z', expanding and integrating,

$$Ix'_wz'_w=Ix_wz_w-\frac{dwr}{g}-\frac{ewh}{g}+\frac{ed(W+w)}{g}. \quad (12)$$

Taking moments about the X and Z axes,

$$d=\frac{wh}{W+w} \quad (13)$$

$$e=\frac{wr}{W+w} \quad (14)$$

Substituting (13) and (14) in (12),

$$Ix'_wz'_w=Ix_wz_w-\frac{w^2hr}{(W+w)g}. \quad (15)$$

Substituting from (8) into (15),

$$Ix'_wz'_w=\frac{wrh}{g}-\frac{w^2hr}{(W+w)g}. \quad (16)$$

Substituting (13) and (14) in (9) and (10), respectively,

$$Ix'_w=Ix_w-\frac{w^2h^2}{(W+w)g} \quad (17)$$

$$Iz_w'=Iz_w-\frac{w^2r^2}{(W+w)g}. \quad (18)$$

If the axes are rotated through an angle a, the product of inertia about the new axes X'' and Z'' is, by definition:

$$Ix_w''z''_w=\int x''z''\ dM.$$

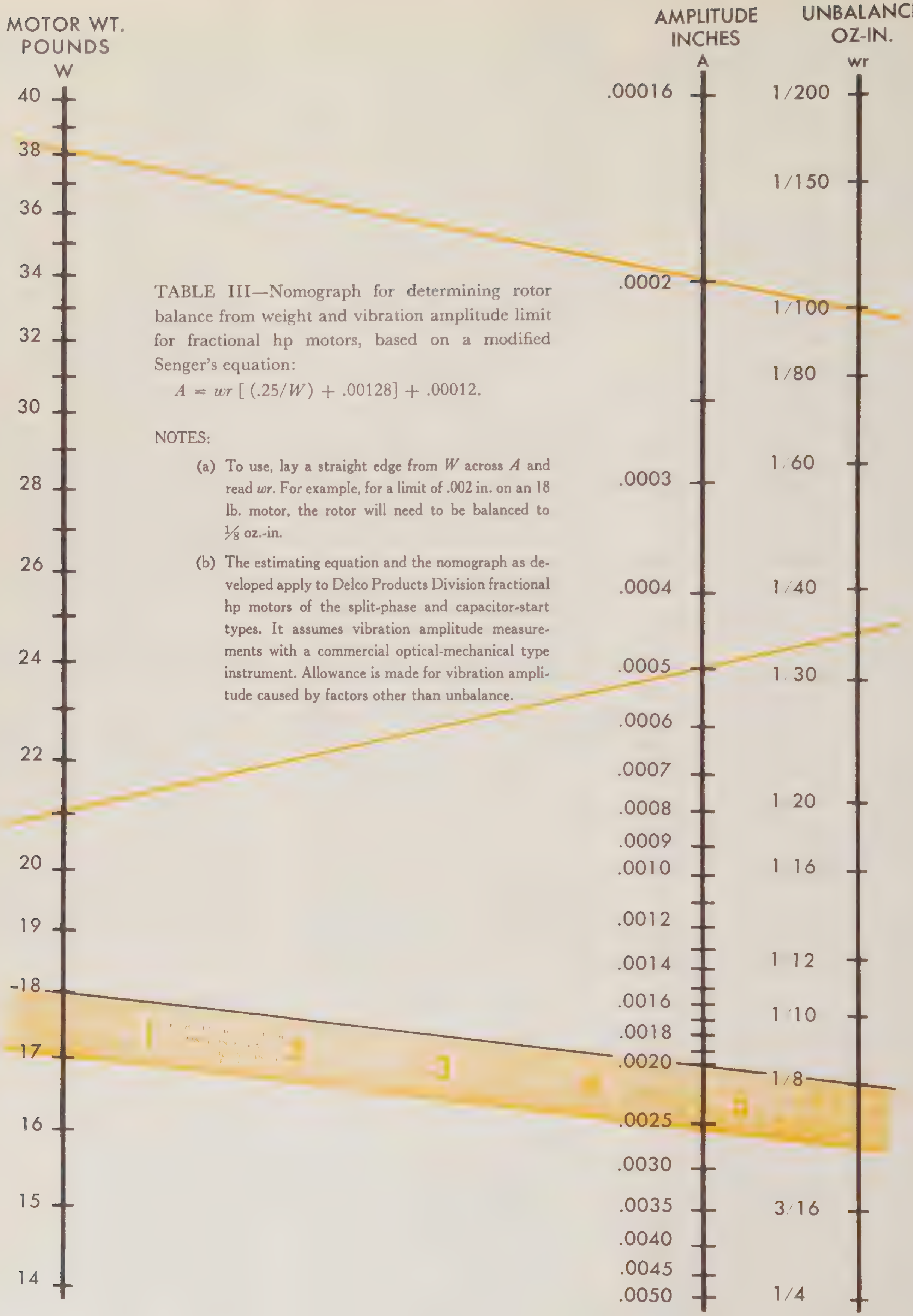


TABLE III—Nomograph for determining rotor balance from weight and vibration amplitude limit for fractional hp motors, based on a modified Senger's equation:

$$A = wr\,[\,(.25/W) + .00128] + .00012.$$

NOTES:

(a) To use, lay a straight edge from W across A and read wr. For example, for a limit of .002 in. on an 18 lb. motor, the rotor will need to be balanced to ⅛ oz.-in.

(b) The estimating equation and the nomograph as developed apply to Delco Products Division fractional hp motors of the split-phase and capacitor-start types. It assumes vibration amplitude measurements with a commercial optical-mechanical type instrument. Allowance is made for vibration amplitude caused by factors other than unbalance.

Substituting the values for x'' and z'' obtained by projection on the X'' and Z'' axes and expanding,

$$Ix''_wz''_w = \tfrac{1}{2}\sin 2aIz'_w + \cos 2aIx'_wz'_w - \tfrac{1}{2}\sin 2aIx'_w \quad (19)$$

where a is the angle formed at the center of gravity by Z' and Z'' of Fig. 6.

Since the X'' and Z'' axes are the principal axes with the addition of w, the product of inertia is zero. Setting (19) equal to zero and transposing,

$$\sin 2a\,(Ix'_w - Iz'_w) = 2Ix'_wz'_w \cos 2a$$

Dividing both sides by $\cos 2a\,(Ix'_w - Iz'_w)$ and substituting equations (16) (17) and (18) in the result,

$$a = \tfrac{1}{2}\tan^{-1}\left[\frac{2rh\left(\frac{w}{g} - \frac{w^2}{(W+w)g}\right)}{Ix_w - Iz_w + \frac{w^2}{(W+w)g}(r^2 - h^2)}\right]. \quad (20)$$

Substituting from equations (6) and (7),

$$a = \tfrac{1}{2}\tan^{-1}\left[\frac{2rh\left(\frac{w}{g} - \frac{w^2}{(W+w)g}\right)}{Ix - Iz + (h^2 - r^2)\left(\frac{w}{g} - \frac{w^2}{(W+w)g}\right)}\right]. \quad (21)$$

Since w is very small compared to W, the terms

$$\frac{w^2}{(W+w)g} \text{ and } \left[\frac{w}{g} - \frac{w^2}{(W+w)g}(h^2 - r^2)\right]$$

may be omitted since their magnitude is negligible. Also the angle a is very small and it can be assumed that $\tan a = a$. Equation (20) thus simplified becomes

$$a = \frac{wrh}{g(I_x - I_z)}. \quad (22)$$

From Fig. 6

$$A = e + aJ \quad (23)$$

Substituting (14) and (22) in (23) and neglecting w in the quantity $(W+w)$,

$$A = \frac{wr}{W} + \frac{wrhJ}{g(I_x - I_z)} \text{ (approximately)}. \quad (24)$$

Since vibration amplitude is ordinarily measured as peak-to-peak value, the right side of equation (24) must be multiplied by 2. When divided by 16 oz., equation (24) becomes the approximating equation (1) presented in the main text.

Lubrication Requirements for Diesel Engines

Diesel engines have more severe lubricant requirements than do gasoline engines, and both have benefited from recent chemical additives to oils. Additives are one route to better lubrication. The way is clear for further improvements.

by ROBERT A. PEJEAU
Cleveland Diesel Engine Division

Synthetic additives have helped; more lubricant progress is in sight

IN A DIESEL engine, as in a gasoline engine, the primary functions of the lubricating oil are to reduce the friction between moving parts and to dissipate heat. The importance of heat dissipation cannot be overemphasized. It is not sufficient only to supply oil to a bearing; the oil and heat must also be taken away.

Almost any mineral oil of the proper viscosity accomplishes these two main functions in a Diesel engine, but various types of oil exhibit widely different characteristics affecting engine cleanliness, wear, and lubricant life. After consideration of these requirements is made, the similarity between Diesel engine and gasoline engine lubrication ends. The lubrication requirements of a Diesel engine are more severe than in other internal combustion engines. The temperatures are higher and this increases the rate of oxidation of the lubricant; the oil is subject to more contamination due to the type of fuel used, and the piston ring or cylinder wear is greater because of the higher compression and firing pressures involved.

For large, slow-speed Diesel engines, straight mineral oils are adequate for satisfactory performance. In the case of modern, high-speed Diesel engines, it is apparent that these oils are not meeting the severe operating requirements.

As a result of improved refining techniques and the development of chemical formulations which are added to the oils, the lubricants available today are far superior to those in use 15 or even five years ago. It is paradoxical that the necessity for the addition of chemical formulations, as used in present day lubricating oils, was brought about by improved refining techniques. Refining is merely a process of conditioning and purifying crude oil. However, as refining becomes more thorough so that more and more impurities are removed, some of the desirable constituents are also removed. In order to supplant these desirable constituents, chemical formulations, commonly referred to as *additives* were developed. Evidence of the success of these oils is the fact that practically every filling station in the nation carries additive type or heavy duty lubricating oils for passenger cars.

Even though additive lubricating oils are more expensive than the straight mineral variety, they are much cheaper to use from an overall economic consideration. A Diesel engine can operate on a straight mineral oil but the oil service life will be shorter; the engine wear rate will be higher, and the frequency of engine overhauls will be increased.

It is not intended to infer that additives are the answer to all lubrication problems in Diesel engines, for with higher concentrations of these materials, other difficulties have been encountered. In any event, the possibility of further lubricating oil development is still as bright as it was on the day Col. Edwin L. Drake drilled his now-famous Pennsylvania oil well in 1859.

Changes and improvement in Diesel engine designs are inevitable and the need for improved oils will move along with this progress. Synthetic lubricants are already providing hints of interesting possibilities.

Engine-Transmission Relationship for Higher Efficiency*

The evolution of automobile transmissions from belt and chain drives of the 1890's to modern automatic shift and torque converter transmissions is described and recent advances in high compression engines are summarized. The mating of an ideal engine and an ideal transmission into a combined power package is termed the most fundamental development facing the industry today. Performance criteria are established for an ideal transmission. Successful development of such a power package is presented as offering a 50 per cent increase over the present miles per gallon figure for all motor vehicles.

Engineers have been concerned about engine-transmission relationship since the beginnings of the automotive industry in the 1890's. Almost since belt or chain drives were the accepted means of power transmission, there has been a continuous effort to develop the "ideal" transmission to assure high torque for starting, accelerating, and hill climbing, and allow more flexibility in using the power from the engine at maximum efficiency.[1]

The power plant-transmission problem might have been lesser had some other than the gasoline engine won acceptance in mass production vehicles. Early proponents of the steam engine and electric drive pointed to built-in transmissions with easy drives, but the gasoline engine was accepted for mass production. It proved lighter, more reliable, low in cost, and used a widely available fuel. However, even after more than a half-century of development, the power-speed relationship of the accepted engine remains a problem.

Today's automatic shift and torque converter transmissions and combinations of both are evidence that the efforts of transmission engineers have been rewarding. However, just as there are many future gains in efficiency possible by increasing compression ratio of engines, there are many gains in economy possible by developments in transmissions to utilize most effectively the potentials of the engine. There are many transmission variables and many engine variables. The authors believe that *the combined engine-transmission power package is the most fundamental development facing the industry today.* This paper shows the large gains in economy which such a power package can make possible; it presents *what the engine wants the transmission to do*, and leaves to transmission designers of the present and future the problem of *how* it can be done. It is hoped that transmission engineers, in the discussion of this paper, will set forth *what the transmission wants the ideal engine to do.* The problem is as broad as it is long.

Review of Transmission Advances

The inherent characteristics of the gasoline engine always have been recognized by transmission designers as limitations. An interesting history of the search for better transmissions is revealed by a review of the mechanisms studied by the Research Laboratories Division in the past 30 years. A 1925 report lists the kinds of transmissions studied up to that time. Among the nine transmission types were: hydraulic (Fig. 1), variable throw (Fig. 2), inertia (Fig. 3), sliding gear (Fig. 4), over-gear, synchronized, constant mesh, planetary, and electric. Models of most of these types had been built and tested either on the dynamometer or in a car and the principal opinion which may be drawn from this early work is that an infinitely variable transmission has been an attractive goal since the 1900's.

The Research Laboratories Division learned much from a double toric friction transmission project started in 192

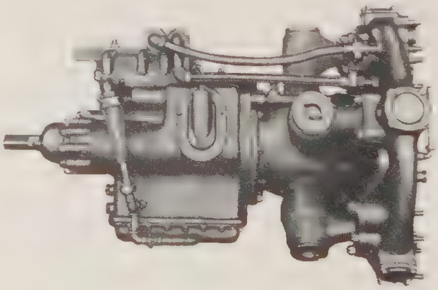


Fig. 1—Early Manley hydraulic transmission of the piston pump and motor type aimed to provide infinitely variable drive.

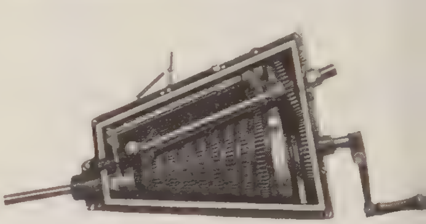


Fig. 2—In eight-step gear transmission of early 1920's engineers continued to grope toward infinitely variable ratio change.

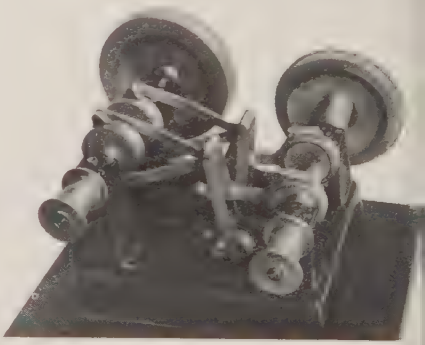


Fig. 3—Constantinesco transmission, also built and tested in early 20's, was akin to mechanical torque converter and also sought infinite ratio change.

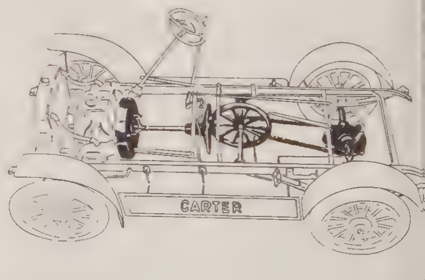


Fig. 4—Transmission of Cartercar of 1900's consisted of disc and sliding friction wheel to provide variable forward and rear speeds. Cartercar Company was purchased by GM soon after Corporation's organization in 1908.

*Adapted and condensed from a 6,000 word paper of the same title prepared by the authors and presented at the Society of Automotive Engineers 1952 summer meeting at Atlantic City, N. J. Its publication here is by permission of the S.A.E. Copies of the original are available on request from the authors.

By DARL F. CARIS and
RALPH A. RICHARDSON
Research Laboratories
Division

A challenge
to transmission engineers
of today and tomorrow

nd continued through the early 1930's Fig. 5). This variable friction transmission was fully automatic and weighed bout 250 pounds. It had a maximum fficient range from 87 to 91 per cent at esigned torque. Overall gains of 20 per ent in fuel mileage were obtained on oss country trips.

The *approach* to the project was novel nd may have been as important as the ndings. In early 1928, before a mechasm was chosen, computations based on ynamometer test data from a standard utomobile engine were made to deterine the performance and economy ains to be expected with an ideal, infitely variable transmission. Assumptions ere that the engine would always be perated at the speed and load of miniium specific fuel consumption and ever above the maximum power point. was recognized that the best performnce and economy of a car equipped ith an infinitely variable transmission quired an automatic method of conol. Accordingly, one of the first autoatic control systems based on an analys of engine-transmission relationships as developed.

Although the development was never ut into mass production for economic nd other reasons, the friction transmison project contributed importantly to evelopment of today's automatic transissions. It gave a baseline in performnce, control, and economy which could nly be obtained in an actual car. It also tablished five requirements which an eal production model transmission ust meet:

(a) Eliminate the clutch pedal.
(b) Eliminate hand gear shifting.
(c) Give added safety by making driving easier.
(d) Automatically provide the ideal ratio for every driving need.
(e) Take full advantage of the inherent economy of the engine while providing required performance in acceleration and hill climbing ability.

Several present transmissions obtain a full measure of the first three points. Attempts to obtain full advantage of the last two have not yet been successful and are presented as challenges herein.

The past 15 years, and particularly since 1946, has been a period of rapid development in both transmissions and spark ignition engines. The automatic shift and torque converter were developed, followed by many combinations of the principles involved in both types. Higher compression engines have been developed, with still more to come.

Since obtaining maximum economy depends as much on knowledge of engine characteristics as on transmission mechanisms, a review of the state of knowledge in engine development seems helpful in establishing transmission characteristics. It is noted in the discussion of engine development, below, that the Research engines mentioned were tested in standard General Motors cars. The results of this work reflect the thinking of the Research Laboratories Division, which is independent of GM's production Divisions.

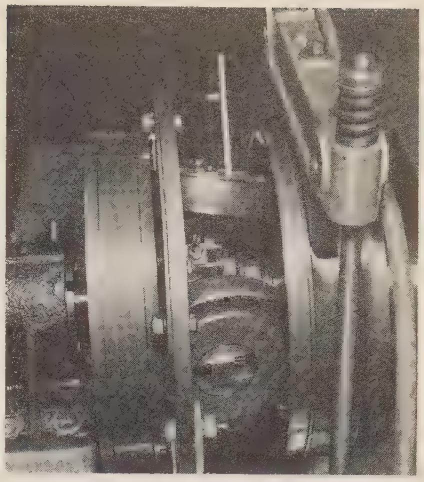


Fig. 5—Torus race and roller assembly of double toric friction transmission undergoing dynamometer test. Of more than 400,000 miles of testing given to the more than 30 of these units built, some 115,000 miles were on dynamometer durability tests. Seventeen others went into passenger cars and were subjected to more than 300,000 miles of road test.

Review of High Compression Engine Development

Charles F. Kettering[2] and Charles L. McCuen[3] have published papers demonstrating that higher compression ratios are the key to higher efficiency. They have shown by a series of experiments on both single- and multi-cylinder engines that large gains in economy are possible with compression ratios of 12:1 or more.

There are, of course, many other factors which contribute to the overall efficiency

Fig. 6—Cadillac test cars on an Arizona desert road near the Phoenix Proving Ground lined up in the same l. to r. order as the data in the chart. Note especially that compression ratio increased from 4.25 in 1915 to 7.50 in 1951 and that the engine-rpm-to-car-speed ratio N/V on the 19XX car was 32.9, which figure resulted in high miles-per-gallon qualities.

	1915	1935	1951	19XX
BORE	3-1/8	3-3/8	3-13/16	3-3/4
STROKE	5-1/8	4-15/16	3-5/8	3-1/4
DISPLACEMENT	314	353	331	287
COMPRESSION RATIO	4.25	6.25	7.50	12
BRAKE SPECIFIC FUEL	–	0.63	0.55	0.46
MAX BRAKE TORQUE	152	234	268	266
MAX BMEP	73	100	122	140
MAX BHP	77 @ 2600	*108 @ 3000	*133 @ 3600	*148 @ 4000
HP/CU IN	0.245	0.306	0.402	0.522
WHEELBASE	122	128	126	126
CURB WEIGHT	4140	5050	4440	4440
ENG RPM/MPH	46.5	51.4	40.2	32.9
AXLE RATIO	5.07	4.6	3.36	2.75

*AS INSTALLED HORSEPOWER GM TEST CODE CORRECTIONS AND PROCEDURES

of the automotive engine besides the ratio of the volume of gas in an engine cylinder at the beginning of the compression stroke to its volume at the end of the stroke. Mechanical and volumetric efficiency, carburetion, spark advance, and other factors are important. It is assumed, however, that in modern engines these factors have been fairly well exploited, and therefore the key to further improvement in engine efficiency lies primarily in higher compression ratios.

Improved fuel quality, evident in higher chemical octane numbers, and improved engine design, often described in terms of higher "mechanical" octane numbers, both are factors which permit compression ratios to be increased. Petroleum technologists have improved the quality of fuel at an average rate of about one octane number per year over the past 25 to 35 years. Mr. McCuen, in 1951[3], demonstrated with test data (Fig. 6) on standard Cadillac cars of 1915, 1935, and 1951, and a fourth experimental model, 19XX, that the automotive industry had made vast gains both in improving engine performance and fuel economy during the 36-year span of the car models (Fig. 7).

The 19XX car is a product of continuing development work aimed at high compression ratio, and 12:1 engines are expected to be ready when fuels of high enough octane number are available. (For the tests it used experimental fuel of about 103 octane number; whereas the 1915 Cadillac required 60, the 1935 car 67, and the 1951, from 85 to 92.) The 19XX car's performance design was deliberately matched to the performance design of the 1951 standard Cadillac. Therefore the entire gain in efficiency

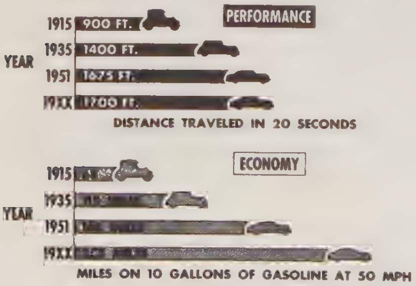


Fig. 7—Using 20 seconds acceleration from a stop at full throttle as a performance measure, the standard 1951 Cadillac was 86 per cent better than the 1915 car. In the economy test, the 1951 model gave nearly 2¾ miles against each mile with the 1915 car. The 19XX car, with its 12:1 compression ratio engine and transmission providing a low N/V ratio, traveled almost four times as far on ten gallons fuel as did the 1915 car.

from its 12:1 engine and the resulting low engine-rpm-to-car-speed N/V ratio was taken up in economy, as the test data proved (Fig. 7).

The 19XX car tested so well in both the performance and fuel economy categories because of both the high chemical octane number of its fuel and because of the high "mechanical octane number" of its design. Perhaps a better illustration of how engine design features permit operation at higher compression ratios *on a given fuel octane number* was an experimental 253 cu. in. engine built to operate at 7.7 compression ratio *on regular gasoline.* This Research engine was installed in a stock car and tested against a stock car of the same model, the engine of which had a compression ratio of 6.7. The stock car with the experimental engine proved to have a margin over the standard model of 17.5 per cent in performance and 20 per cent improvement in economy (Fig. 8).

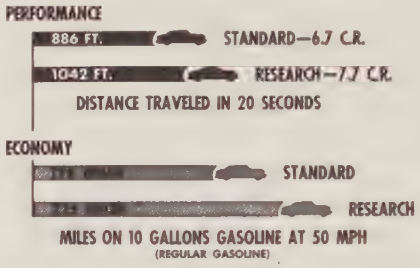


Fig. 8—Two test cars were identical except that one had experimental engine with a high "mechanical" octane number reflected in higher compression ratio. Identical fuels were used and the experimental engine was deliberately designed to improve both performance and economy, as the test data proved.

The above-described sets of tests (Figs. 7 and 8) summarize the achievements of the past few years in increasing engine efficiency. Many of the early design problems in connection with high compression engines have been completely solved since results of the first 12.5:1 engine were published in 1947[2]. It was then demonstrated that when the structure was designed rigid enough to carry the high compression loads without excessive distortion, roughness was no longer an insurmountable problem. This fact was further substantiated by the results of experience gained with a 287 cu. in. V-8, high compression fuel test engine which was built and supplied to many oil companies for use in fuel development.

Main design lessons have been: (a) compression ratios above 8:1 require bearings on both sides of each crank throw in order to achieve the smooth operation of some recent engines; (b) these compression ratios require overhead valves in order to maintain high volumetric efficiency; and (c) a satisfactory means for finding room for overhead valves and spark plug at the high compression ratio is to build larger bore, short-stroke engines.

Considerable work was done to prove that the engine designer had quite a wide selection of stroke-to-bore S/B ratios without sacrifice in fuel economy. At one stage, two engines having equal displacement and compression ratio but with an S/B ratio of 0.71 and 1.33 in the separate cases were tested in identical cars and cross country fuel economy runs resulted in almost identical fuel requirement (Fig. 9).

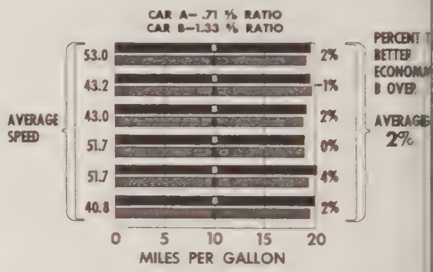
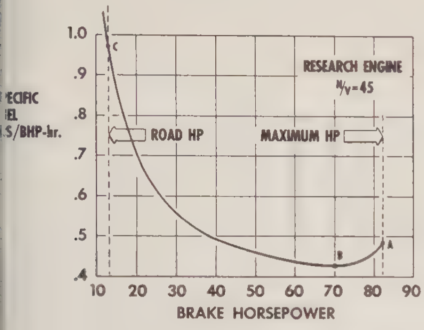


Fig. 9—Early fuel economy tests on short runs proved the fuel requirement to be almost identical for cars A and B, the only variable being S/B ratios being .71 and 1.33, respectively. Fixed jet carburetors were developed for the engines and cross country tests at six average speeds substantiated the belief that the variable did not materially affect economy.

Work on high-compression engines, incorporating high "mechanical" octane numbers, has resulted in a trend toward adoption of these engines for mass production. The trend must grow in step with the findings of petroleum technologists who are seeking ways of increasing chemical octane numbers. Viewed from a national perspective, a 20 per cent improvement in fuel economy (Fig. 7) becomes impressive indeed. Since the yearly consumption of gasoline in the United States is 40 billion gallons, it *would amount to a saving of 8 billion gallons or, at 25 cents a gallon, 2 billion dollars.* Such is the incentive in engine development alone. The incentive for development of a combination power-transmission system is considerably greater, as is shown below.

Ideal Engine-Transmission Relationship

The analysis of the ideal engine-ransmission relationship may be de-eloped around the 253 cu. in. Research ngine with its 7.7 compression ratio and vhich outstripped its standard 6.7 ompression ratio counterpart by 20 er cent in fuel economy and 17.5 per ent in performance (Fig. 7). The elationship between brake specific fuel nd brake horsepower is different, of ourse, for each selection of constant pm. Consider the typical cross section urve (Fig. 10) at 2,000 rpm. This may



ig. 10—Typical cross section curve at 2,000 rpm.

e called a cross section curve, since it hows how the specific fuel consumption aries in the cross section between road oad and performance power. This curve s obtained by leaning the air-fuel *A/F* nixture from point **A**, the mixture ratio t which the engine develops maximum ower, to **B** where it develops best conomy. The throttle is closed from vide open at **B** to the throttle opening equired to develop road load horsepower t **C**. The specific fuel consumption at oint **B** is obviously only a fraction of hat at point **C**. In fact, at the minimum pecific fuel consumption which occurs t 70 bhp, the specific fuel is only 0.43 b/bhp-hr, in comparison with the road oad point **C**, 13 bhp, where the specific uel consumption is 0.97 lb/bhp-hr.

Superimposed in Fig. 11 is a whole family of individual cross section curves. It shows the relationship between specific fuel consumption (lb/bhp-hr) and brake horsepower under a wide variety of operating conditions for the Research engine. One might look at Fig. 11 as a character sketch of an engine, because it discloses a great deal about how the engine responds to almost any operating conditions.

When enough of the individual cross section curves are included, the whole group can be enclosed by an enveloping curve. Under the operating conditions represented by any point on this curve, the engine develops its best economy. It is apparent, therefore, that if the ideal transmission is to deliver best economy, *it should permit the engine to operate on this curve at all times*. In other words, the transmission controls should always adjust the engine setting to operate at the point of minimum specific fuel consumption.

In order to illustrate the method of arriving at the engine-transmission relationship for best economy, the following typical conditions are discussed: (a) minimum engine speed, (b) typical point of minimum specific fuel consumption, (c) typical performance calculation, and (d) engine limited to speed of maximum horsepower.

First, the horsepower P required to drive the car at various speeds is computed from the formula:

$$P = V\,(KW + K_1AV^2)/375$$

where $K = 0.012$
$K_1 = 0.00125$
W = test weight (car weight + 600 lbs test weight)
A = projected frontal area, sq. ft.
V = car velocity, mph.

In this analysis a stock car having $W = 4{,}000$ lbs is used.

Fig. 12 shows such a road load power requirement curve for a standard stock car. It can be noted from the figure that it required 3.2 bhp to drive the vehicle at 20 mph on a level road. Referring again to Fig. 11, it can be seen that 3.2 bhp is developed at point **A** on the curve of best economy. At this point the engine uses fuel at the rate of 0.70 lb/bhp-hr, from which miles-per-gallon G can be computed from the relation:

$$G = \frac{VC}{FP}$$

where V = miles per hour
C = lb/gal. of gasoline
F = specific fuel consumption, lb/bhp-hr
P = horsepower.

Arbitrarily, the minimum speed of the engines used in these studies was limited to 400 rpm, which accounts for the relatively high fuel consumption at point **A**. In choosing 400 rpm as the minimum speed, the authors are fully aware that it may be on the low side for present engines. However, remember that the objective of this discussion is to establish the ideal engine-transmission relationship for best economy. The engine has to be throttled considerably in order to develop 3.2 bhp at 400 rpm. (An engine having a low displacement figure would, of course, operate more efficiently at this road load.)

The second typical condition illustrates the point of minimum specific fuel consumption. From the road load power curve, note that at 60 mph it requires 26 bhp to drive the car on a level road. Fig. 11 shows that at 26 bhp, point **C** on the curve of best economy, the engine uses fuel at the rate of 0.445 lb/bhp-hr, as compared to 0.70 lb/bhp-hr at 20 mph where the 400 rpm minimum speed limitation made it necessary to close the throttle to meet road load horsepower requirements. At level road driving, the transmission would operate the engine on the solid, minimum specific fuel envelope curve.

The third typical condition which must be considered is the required performance, represented by acceleration and hill climb in the car, and by horsepower

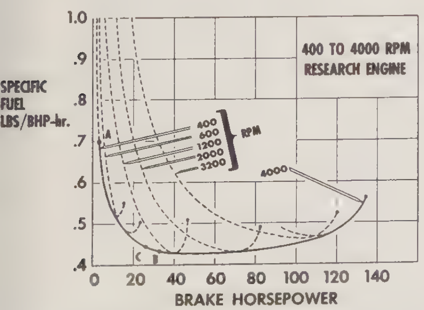


Fig. 11—Family of cross section curves at various engine rpm's.

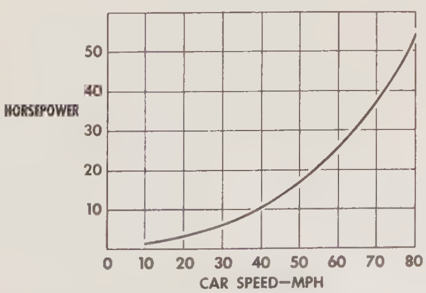


Fig. 12—Road load hp curve of a 4,000 lb. stock car at varying mph.

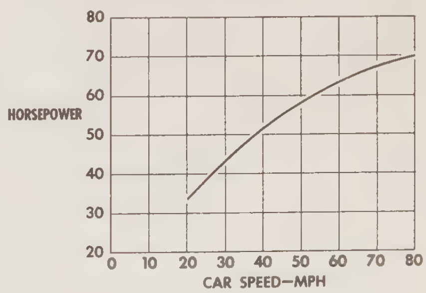


Fig. 13—Curve of power required at rear wheels to match stock car performance of Fig. 12.

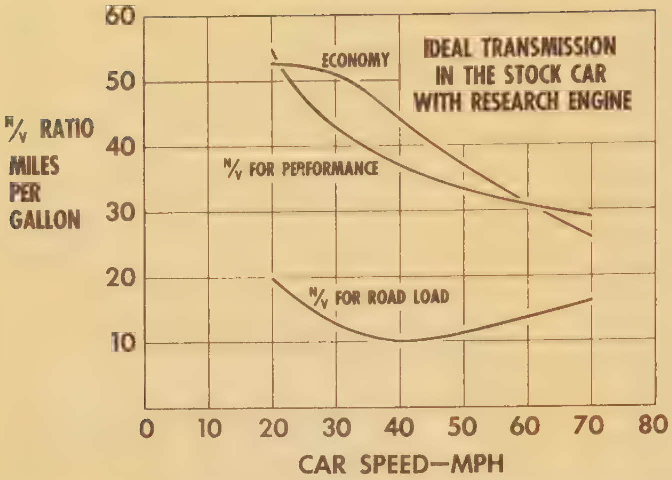


Fig. 14—Constant speed, level-road economy curve of ideal engine-transmission relationship.

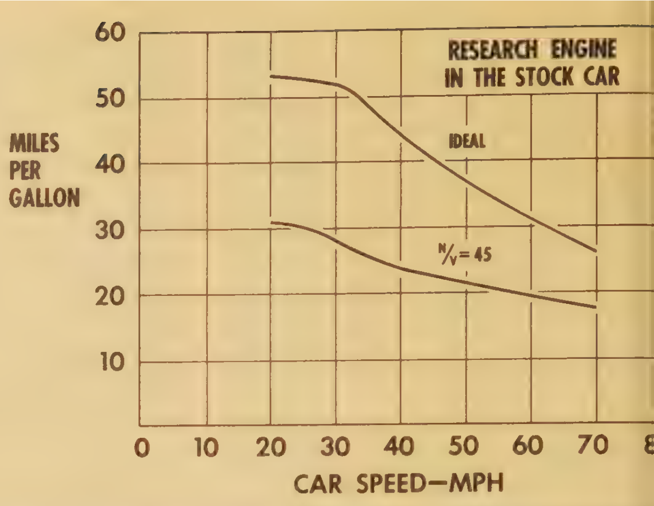


Fig. 15—Constant-speed, level road fuel economy curve of ideal transmissio vs. transmission with fixed N/V ratio.

available for these factors to the engineer. In this example, operating conditions were selected to match the performance of the standard 4,000 lb stock car (Fig. 13), which requires 30.2 bhp at 20 mph in addition to the 3.2 required for road load, or a total bhp of 33.4. In order to develop 33.4 bhp and still keep on the best economy curve (Fig. 11), the transmission must obviously permit the engine to increase its speed to 1,100 rpm (point **B**). It is seen that in this ideal engine-transmission relationship, the transmission should in effect act as a moderator to keep the engine always operating at its best efficiency to develop the required power. Once the desired performance speed is determined, the relation between engine rpm and vehicle speed N/V can be established. The transmission controls would pick the engine speed to develop the required horsepower at a point of minimum fuel consumption. This is again on the solid envelope curve.

Fig. 14 shows the level road, constant speed fuel economy over the speed range from 20 to 70 mph resulting from the above ideal engine-transmission relationship, assuming no losses between the engine and road. Also shown is the road load ratio of engine-rpm-to-car-speed N/V and the N/V to give the stock car performance over the speed range. For instance, at 40 mph the road load N/V is 10 and performance N/V is 37. It is recognized, of course, that much higher N/V ratios are required to start the car from rest.

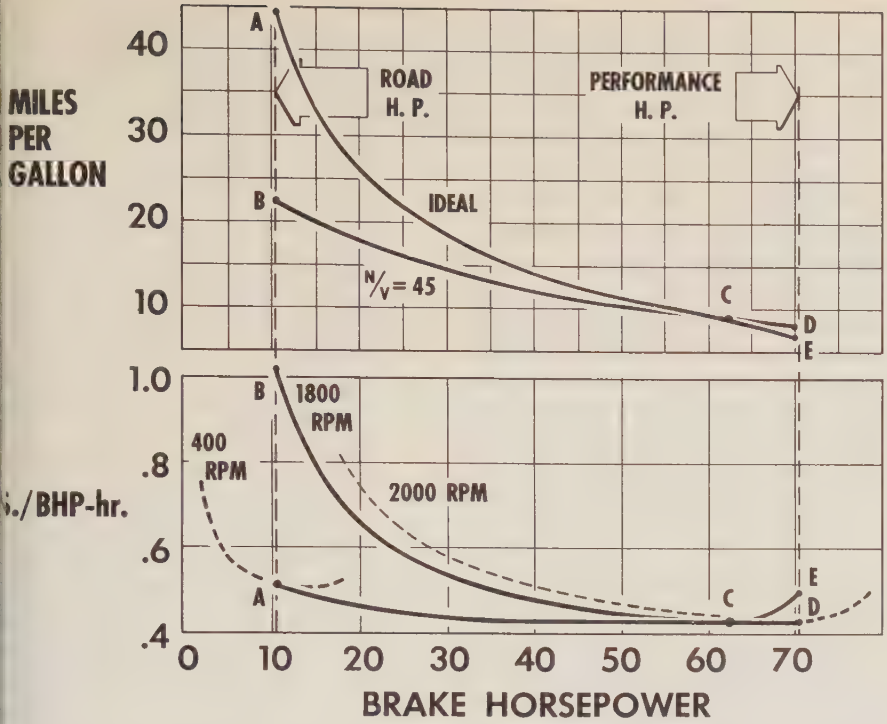
Fuel economy figures such as those shown in Fig. 14 are difficult to evaluate unless they can be compared with a familiar yardstick. Fig. 15 compares level road, constant speed fuel economy with the two types of transmissions, the ideal and fixed N/V in the stock car equipped with the Research 253 cu. in. engine. The curves were computed without considering loss in efficiency between engine and road in either case. The data are presented on a comparative basis, and it is felt that from the engine man's standpoint it is fair to ignore transmission losses in this study since they vary with the mechanism used to obtain the results. Moreover, since this study does not propose a transmission design, the actual losses are unknown. The figure shows that the use of the ideal transmission would make possible gains in constant speed fuel economy of from 70 to 48 per cent over the speed range from 30 to 70 mph. This analysis presents what is inherently possible from the engine standpoint. How much of this is obtained will depend upon the transmission design; but even allowing for large losses, a large potential gain remains.

On the other hand, automobiles are not driven on level roads at constant speeds very much of the time. Fig. 16 is presented to show how operating conditions affect the gains in economy realized from the use of the ideal transmission. Two curves are shown in the lower half of Fig. 16 illustrating the relation between specific fuel consumption and brake horsepower for the experimental 253 cu. in. engine in the stock car at 40 mph. The ideal transmission permits the engine to follow the best economy curve, whereas the standard transmission with fixed N/V ratio of 45 forces the engine to follow the other curve. The stock car requires 10.5 bhp to propel it at 40 mph on a level road. On the best econom curve at point **A**, 10.5 bhp can b developed at 400 rpm with fuel consump tion of 0.518 lb/bhp-hr, while it require 1.02 lbs/bhp-hr to develop the same 10. bhp at 1,800 rpm (point **B**) on the fixe N/V curve. Now, point **B** is equal t 22.4 mpg and point **A** corresponds to 4 mpg as plotted on the upper set of curves It is apparent that under these condition it is possible to almost double the mile per gallon if an ideal transmission wer possible.

The curves of Fig. 16 also show tha as the throttle is opened with the stand ard or fixed N/V transmission to develo more horsepower for performance, th fuel consumption is rapidly reduced unt at **C**, with the throttle open, it exactl equals the fuel consumption with th ideal transmission. At **E**, correspondin to 70.5 bhp required for full performanc at 40 mph, the standard transmission ha required the engine to cut in the riche A/F power mixture, while the idea transmission has permitted it to increas the speed to 2,000 rpm and develop th 70.5 bhp without enrichening (point **D**)

This ability of the ideal transmissio to let the engine operate in the lowe speed range without enrichening, result in from 10 to 15 per cent improvemen in economy over present transmission whenever the engine is operated at fu throttle. At the higher car speeds would, of course, be necessary to en richen the A/F mixture in order to obtai performance and top speed.

The ideal transmission would obviousl limit the top speed of the engine to th point at which it develops maximur power. In some cases this would result i



g. 16—Forty mph cross section curves of ideal engine-transmission relationship vs. fixed engine speed to speed N/V ratio.

wer specific fuel consumption and ghtly higher top speed.

Analysis of Fig. 16 discloses several iportant facts about the gains in econny with the ideal as compared to the indard transmission. These are the ctors which are important in the comnation power-transmission system:

(a) The greatest improvement in economy occurs at road load, around 98 per cent in this case.

(b) The improvement in economy rapidly decreases at greater loads.

(c) Since the driver is continually operating between road and performance power, his overall gain in tank mileage would obviously be much less than the 98 per cent he obtained under constant speed, level road conditions.

(d) The effect of country and city types of driving on economy would be greater with the ideal transmission. However, use of the ideal transmission would always result in an improvement in economy under all conditions. This fact represents an important advantage, since a large percentage of fuel is used in city driving.

(e) With the ideal transmission, road load economy is independent of performance, while with the standard transmission the greater the performance, in general, the lower the road load economy.

(f) The higher the performance factor, the greater the economy gains resulting from the ideal engine-transmission relationship.

In the foregoing discussion, an experimental Research engine was used to illustrate the gains to be obtained by use of the ideal transmission. It might be interesting to apply the same engine-transmission relationship to a standard production car and engine. The curves in Fig. 17, represented by solid lines, show level road, constant speed economy of the standard car compared to the same car with the ideal transmission. Both curves were computed by assuming no losses between the engine and the road. It is apparent that improvements of 70 to 30 per cent are possible in road load economy over the speed range from 30 to 70 mph with the ideal engine-transmission power package.

In computing the dotted curves shown by Fig. 17 a 20 per cent loss in efficiency was arbitrarily assumed between engine and road. It can be seen that the actual values of mpg have been reduced in both cases; but even under these conditions, a 60 to 18 per cent improvement in economy is shown.

Fig. 17 also shows the actual measured level road, constant speed economy of the standard car for comparison. Again, it must be emphasized that cars are not driven at constant speed on level roads and that the improvement in overall tank economy, while substantial, is not likely to be nearly as great with the ideal transmission as is indicated by these constant speed economy curves.

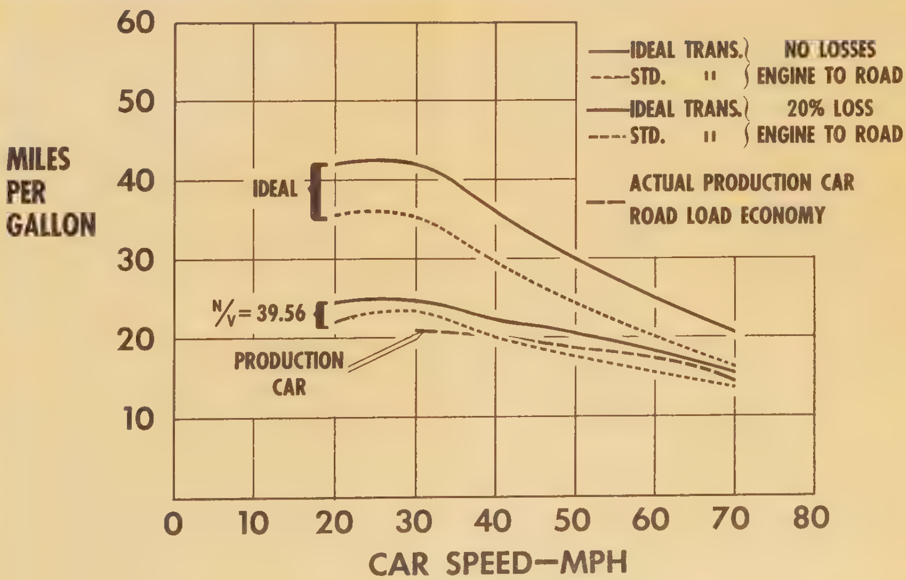


Fig. 17—Constant speed, level-road fuel economy comparison curves of production car and ideal engine.

Summary of Advantages

While it is difficult to assign firm values to the possible gains from an ideal engine-transmission relationship without the benefit of actual tests, it is believed to be entirely justifiable to predict a future overall saving of 25 to 35 per cent in the nation's fuel bill by transmission developments. This is about half of the theoretical gains shown in the theoretical analysis made at road load.

It is realized, of course, that this improvement must be achieved without sacrificing the pleasing characteristics which make present automatic transmissions so popular. In fact, the so-called pleasability will be greatly improved with the ideal transmission in combination with engines up to modern standards of noise and smoothness. The power-transmission package would bring users a new concept in motoring pleasure and economy.

One reason it is so difficult to foresee all the gains resulting from an ideal power-transmission system is that it so completely changes the nature of both engine and transmission.

The engine, for instance, would seldom operate much under 70 to 80 per cent of its full power output. One of the car manufacturer's biggest problems results from operation by some drivers at very light loads. One of the principal causes of spark plug fouling is light load operation. There is also a good possibility that elimination of light load operation would reduce octane depreciation from deposit build-up because a good share of combustion chamber deposits, particularly those which are likely to cause pre-ignition and wild ping, are accumulated during light load running. Anything which reduces combustion chamber deposits results in creating "mechanical" octane numbers or, in this instance, "transmission" octane numbers. The fact that, in the low speed range where knock is critical, the engine would not be permitted to operate at full power, might contribute somewhat to its mechanical octane numbers.

It is unlikely that an engine operating near its full power output at all speeds would need a vacuum spark advance. The vacuum spark advance or its equivalent is employed on most engines because of the slow-burning light load mixtures. Elimination of the vacuum spark advance would be a welcome simplification.

Engine valve timing requirements would need to be carefully investigated under the new operating conditions of the ideal transmission to provide good high speed breathing together with solid low speed performance.

An ideal transmission might also simplify carburetion because of the near full throttle operation. Operation at low vacuum might improve oil control and influence the deposit accumulation picture because less oil would get into the combustion chamber. In other words, the development of a commercial ideal transmission would open up a whole new field of engine development.

Up to the present time, automotive transmissions have generally been developed with the object of eliminating the clutch pedal and thereby making driving easier and more pleasant. The use of the ideal transmission-engine combination would add the incentive of much improved efficiency without sacrificing other desirable features in any way.

Conclusion

A summary of the gains in economy which are possible with a combination of high compression engines and ideal transmissions, shows the incentive for further intensive work. This paper shows how a gain of from 25 to 35 per cent is easily possible with an ideal transmission. It also shows that large gains of 25 to 35 per cent are possible with engines of 12:1 compression ratio. By obtaining the advantage of gains from both high compression engine and ideal transmission developments through further research, *a total saving of 45 to 60 per cent could be made.*

It seems entirely possible, therefore, to reduce gasoline consumption by half without a sacrifice in car size, performance, or roominess. To obtain a 50 per cent increase in the present miles per gallon with normal driving is indeed an incentive for automotive engineers to take advantage of the potentials in the high compression engine and the ideal transmission.

Acknowledgment

The authors wish to acknowledge the many helpful suggestions in the preparation of this paper and the contributions of their associates in the Research Laboratories as well as in the Central Office engineering groups and manufacturing Divisions.

Bibliography

1. James, W. S., "An 'Ideal' Transmission," *SAE Journal*, Vol. 54, No. (August 1946), p. 50.
2. Kettering, C. F., "More Efficien Utilization of Fuels," *SAE Journa* Vol. 55, No. 7 (July 1947), p. 31 *SAE Quarterly Transactions*, Vol. 1 No. 4 (October 1947), p. 669.
3. McCuen, C. L., "Economic Relationship of Engine-Fuel Research," *American Petroleum Institute Proceeding* Mid-year meeting, Annual meeting 31 M (III) (1951).
4. Kettering, C. F., "More Efficien Utilization of Fuels," *Journal of th Society of Automotive Engineers*, Vol. 4 No. 4 (April 1919), p. 263; *Transactions of the SAE*, Part I, Vol. XIV (1919), p. 201.
5. Kettering, C. F. "Fuels and Engines for Higher Power and Greate Efficiency," *SAE Journal* (*Transactions*), Vol. 53, No. 6 (June 1945), p. 352.
6. Campbell, J. M., Caris, D. F., an Withrow, L. L., "Increasing Engin Thermal Efficiencies," *SAE Journa* Vol. 56, No. 12 (December 1948), p 22; *SAE Quarterly Transactions*, V 3, No. 2 (April 1949), p. 341.
7. Greenler, H. R., "Automatic a Semiautomatic Transmissions," *SA Journal* (*Transactions*), Vol. 54, N 8 (August 1946), p. 441.
8. Deimel, A. H., "Hydraulic Transmission Performance," *SAE Journa* Vol. 54, No. 7 (July 1946), p. 38
9. Miller, R. J., "Torque Converters," *SAE Journal*, Vol. 54, No. 8 (Augus 1946), p. 54.
10. Kelley, O. K. and Rosenberger M. S., "Automatic Transmissio Control Systems," *SAE Quarterl Transactions*, Vol. 1, No. 4 (Octobe 1947), p. 559.
11. Deimel, A. H., "Automatic Transmissions—Today—Tomorrow—," *SAE Journal*, Vol. 58, No. 9 (September 1950), p. 23.
12. Cass, Robert, "Motor Vehicl Powerplants and Transmission Lin Units," *SAE Journal*, Vol. 52, No. (August 1944), sup. p. 36.
13. Deimel, A. H., "Hydraulic Transmissions for Motor Vehicles," *SA Journal* (*Transactions*), Vol. 53, No. (January 1945), p. 10.

Engineering Facilities and Product Development In a GM Division (First of a Series)

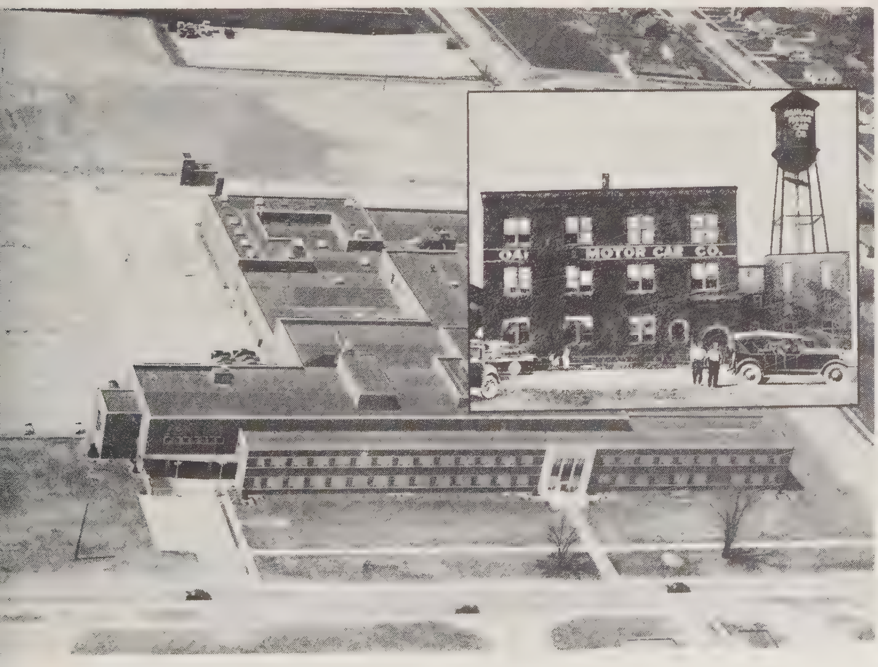
By FORREST H. KANE,
Pontiac
Motor
Division

Case examples
of improvements
in car components

ONTIAC Motor Division's predecessor was the Oakland Motor Car Com-any, which brought out its first auto-obile—a two cylinder model—in 1908 'ig. 1). Until 1911, engineering for this rly entry into the then highly specu-tive automobile field was handled by lonzo P. Brush, who headed a con-ulting engineering firm in Detroit. In at year Oakland organized its own ngineering Department, starting with ss than 25 employes. From this modest eginning the Engineering Department as grown steadily until it now comprises group of 375 people, housed in a odern, air-conditioned structure. The uilding has over 200,000 sq. ft. of floor pace and is precisely designed to serve e Division's diverse engineering re-uirements (Fig. 2).

The facilities available in the new ocation include well-equipped design ooms, a dynamometer laboratory, an lectrical screen laboratory, a cold room, achine, sheet metal, and assembly ops, and ample garage and stockroom ervices for test cars. Also included are supervisory offices, a photographic studio, and car display rooms. Adjoining the engineering quarters is a 750-capacity auditorium equipped for displaying new car models.

Every General Motors engineering force strives to perfect new features which will become acceptable and valuable to the consumer and the company alike. In Pontiac's case, research, product, and production personnel have contributed vastly to the development and widespread acceptance of many automotive advances. Among them are Duco finish, cyanide hardening of transmission gears, harmonic balancer, elimination of controls from steering column, floor control for headlamp beams, mechanical gasoline pump, four-bearing, six-cylinder engine, valve spring dampeners, mounting of engine on neutral axle, tin-plated pistons, interchangeable steel-backed engine bearings, pressure valve cooling, multiple brake seals, gearshift lever mounted on steering column, full-flow oil cleaner, butyl rubber radiator hose, and the Dual Range Hydra-Matic transmission.



ig. 1—Structure housing modern engineering facilities is new home of the Engineering Department. nset shows Pontiac's first main building, in which the Engineering Department occupied third floor.

A brief case history of four of these developments follows.

Harmonic Balancer

A ceaseless search for quietness and smoothness has written an interesting history of investigation, research, development, invention, and progress in the automobile industry. Curiously enough, these advances have come in a series of steps, for as soon as one source of noise was segregated and silenced, another, previously obscured in the general noise level, became prominent. One of the most interesting examples of the corrective measures taken is the *harmonic balancer* (Fig. 3).

In the early 1920's, six-cylinder engines were beginning to challenge the four-cylinder supremacy. They were, on the whole, quieter and smoother than the four. As it happened, however, closed bodies were beginning their climb to popularity, and in the closed bodies a new crop of noises became acutely evident and urgently demanded remedies. Among these was the pronounced ringing noise produced—at certain speeds—by torsional vibration of the six-cylinder crankshaft.

One of the first problems undertaken by the newly organized General Motors Research Corporation (now the Research Laboratories Division) in 1923 was to help find the answer to this annoying torsional vibration. To illustrate this vibration, suppose one takes a

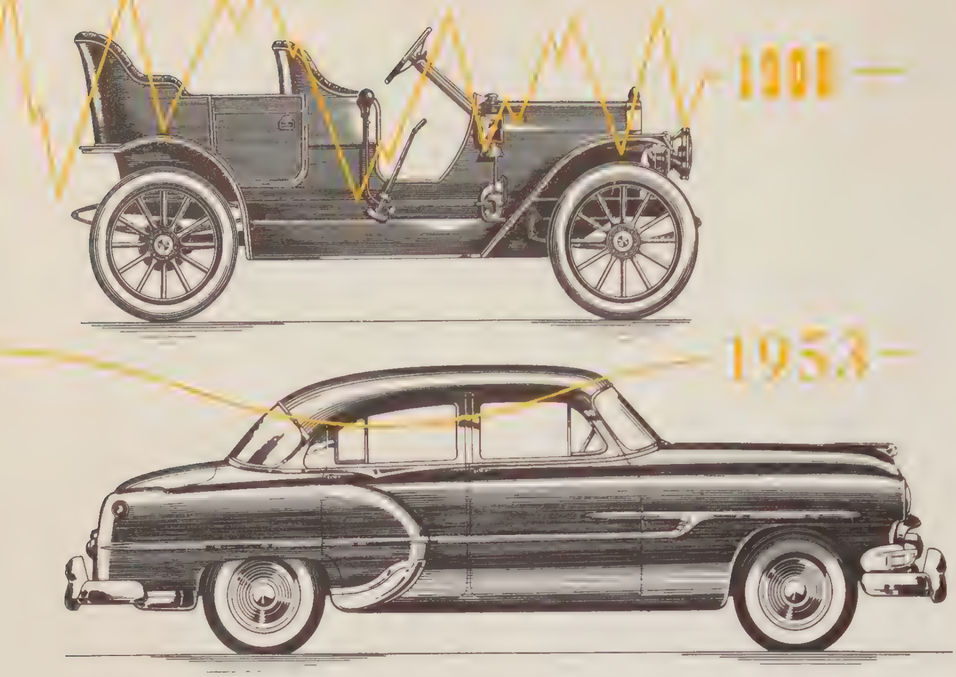


Fig. 2—Sketches of the first Oakland, a 1908 touring model, and a 1953 deluxe sedan portray vast progress. The views display best the improvements in styling, but the sweep of progress is evident in every part of the car.

two-foot slender steel rod; clamps one end in a vise; welds a short bar across the free end to form a long T; then grasping the bar, he twists the rod as though winding a clock. Now suddenly the experimenter lets go of the bar. He finds that the rod oscillates *about its axis* due to the springiness of the steel. This is torsional vibration.

Applying this illustration, the crankshaft corresponds to the rod while the flywheel acts as the vise. Impinging of the power strokes of the engine on the cranks of the crankshaft produce the twisting effect. This causes the crankshaft to oscillate or vibrate *about its axis*, setting up torsional vibration.

Working on the theory that the less the mass, the higher the vibration frequency, a research scientist decided to disassociate the fan from the rotating system of the crankshaft. This he did by driving the fan through a system of coil springs instead of the usual rigid connection to the fan shaft. Under these conditions he found that he had not only raised the speed at which torsional vibration was at a maximum, but the vibration was importantly reduced.

Analyzing what had taken place, it occurred to him that the spring-driven fan might be acting as a reactionary force; that this force, lagging 180° behind the oscillations of the crankshaft, was probably exerting a force in opposition to the crankshaft vibration. Here is how he analyzed it: when the crankshaft, during its torsional vibration period, twisted swiftly, say clockwise, the springs driving the fan compressed due to the inertia of the fan. Instead of the fan immediately following the superimposed oscillation of the crankshaft, it lagged behind. But just at the time that the crankshaft reached the end of its oscillation clockwise, and started back counterclockwise, the compressed springs started the fan moving clockwise; that is, in a direction opposite to the now counterclockwise movement of the crankshaft. Thus, while both these components were *rotating* in the same direction, the superimposed oscillation vibrations of each were in *opposite* directions. Hence, the accelerative force of the fan was working against the accelerative force of the crankshaft oscillation. This opposed action, to a degree, tended to neutralize the torsional vibration.

Following this line of reasoning, a steel disc, much heavier than the fan, was made and mounted on the crankshaft so it was free to oscillate in a limited arc. It was driven through coil springs. By adjusting the weight of the disc and varying the spring tension, a combination was soon found that completely wiped out torsional vibration. Because of its harmonic motion, it was called the harmonic balancer.

At this point, the research findings were communicated to Pontiac, and Pontiac engineers worked out the problem of making a practical and workable design for production application. Many refinements have been made since the harmonic balancer was first used in 1925, but the principle remains unchanged.

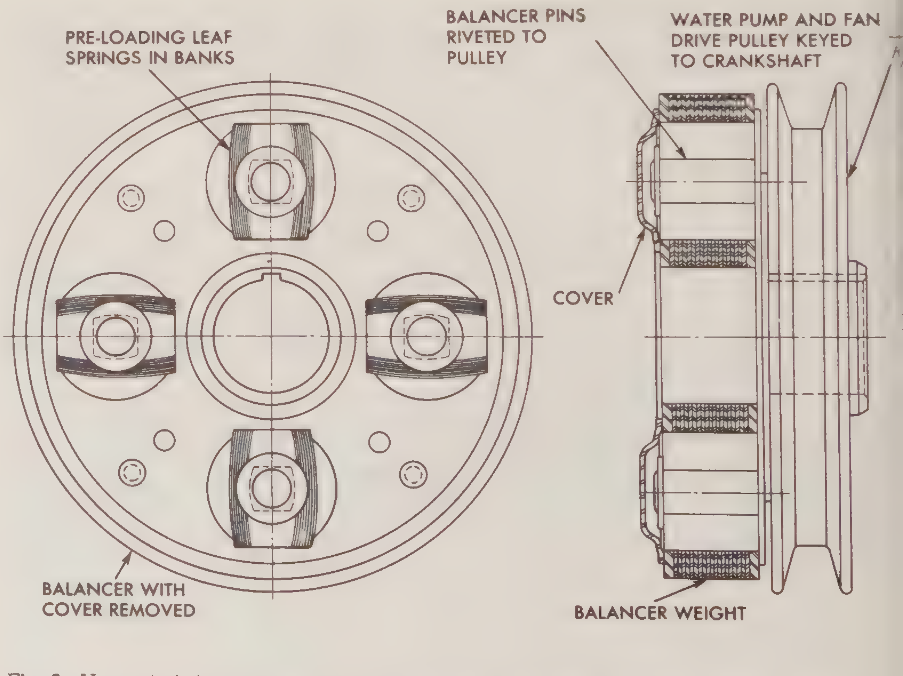
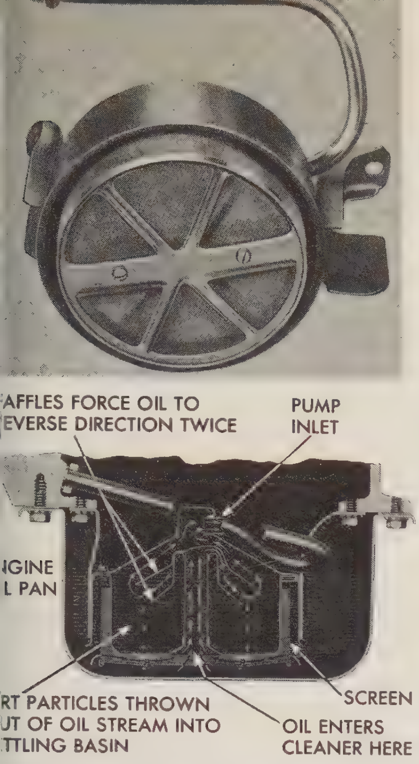


Fig. 3—Harmonic balancer resulted from fundamental crankshaft vibration studies undertaken by Research Laboratories Division in 1923 and subsequent product development at Pontiac.



g. 4—Progress toward Pontiac's 98 per cent ficient full-flow oil cleaner (top) has been steady nce 1939 when the first experimental model sted 2 to 3 per cent efficient. At least 11 types ave preceded the present standard product. The taway view shows how 100 per cent of the oil pplied to engine bearing surfaces passes through e cleaner each time it is recirculated.

Tin-Plated Pistons

In 1929 two pistons for an experimental ngine that had been made undersized ere plated with copper to bring them p to the required diameter. These par- cular pistons worked so well that the ngineer responsible decided to explore e advantages and disadvantages of lating pistons for production use. Some- mes pistons distorted when subjected the high temperatures encountered in e cylinder. This often caused them to ecome scuffed or to *freeze* in the cylinder ores. If the piston skirts were plated with comparatively soft bearing metal, per- aps it would remedy the scuffing prob- m. Several different metals and alloys ere tried during the development period. f these, tin was found to be ideal for e purpose.

Since tin is a soft, ductile metal having xcellent bearing qualities, it makes an eal coating for pistons. This skin, about ne-thousandth in. or less in thickness, ally makes the piston self-fitting; for hen distortion tends to expand the ameter at some local point, the ductile n simply squeezes out in all directions. Thus, it not only relieves the high point, but tends to fill in the surrounding low spots and increases the bearing surface area. For this reason, Pontiac plated pistons can be fitted closer without danger of seizing.

Patented by Pontiac in 1932, the tin-coated piston has been used on all Pontiacs since 1930, as well as by others in the industry. Today, after nearly 23 years of service, nearly 15,000,000 cars have been manufactured using this process.

Built-In, Full-Flow Oil Cleaner

Pontiac engineers first used a built-in, full-flow oil cleaner in 1941 models. As with most developments, it did not pass directly from the inventors' concept to the finished production article. Rather, it evolved from one stage to another in a series of steps, each step contributing something toward final success (Fig. 4).

As a result of complaints from extremely dusty areas, ways and means were sought to minimize the effect of engine bearing wear in these sections. This was the problem which led to the development and use of the built-in, full-flow oil cleaner. Its basic idea was to separate harmful dust particles from the oil by a sudden change in direction of the oil stream, and to permit all oil to pass through the cleaner each time it was recirculated.

A photographic record was kept of the different stages by which an extremely efficient cleaner was finally evolved. First efforts were disheartening; the cleaners were only 2 to 3 per cent efficient. Progressively, the efficiency percentage figure slowly increased: 15, 18, 25; then 42, 52, 60, and to 73 per cent. In 1941 models, the first production models had an efficiency figure of 75 per cent. However, a redesign of the cleaner for the following year boosted this figure to 98 per cent.

(Efficiencies quoted result from measuring the quantity of graded dirt particles removed by the cleaner which would just pass through the conventional 30-mesh oil screen.)

Oil cleaners have been standard equipment on Pontiac engines since the 1941 model.

Dual Range Hydra-Matic Transmisssion Improves Performance and Economy

Prior to the Dual Range Hydra-Matic development in 1951, this transmission (with selector lever in DR position) shifted automatically through 1-2-3 and 4th gears. Dual Range added another "Drive" position which might be called the traffic position, in which the shifts are 1-2 and 3rd. As long as the selector lever is in the traffic DR position, the transmission does not up-shift beyond 3rd gear. Concurrent with this change the rear axle ratio was changed from 3.63 to 1 to 3.08 to 1.

Inclusion of this feature makes possible a much-improved engine, transmission, and rear axle ratio combination. Under traffic conditions, using the 1-2-3 shift, it provides a 4.46 rpm ratio of engine to rear wheel, a value which permits the engine to deliver abundant power for rapid acceleration. It also improves engine braking. In the cruising range—the 1-2-3-4 shift— it importantly reduces engine speed, thereby substantially reducing engine friction, and increases fuel economy. Acceleration was improved by increasing the engine compression ratio from 6.8 to 7.7 and by using premium fuel.

It is interesting to note that with this arrangement the engine turns only 2,260 rpm at 60 mph, whereas a similar model with synchromesh transmission and 4.1 axle ratio turns up to 3,018 rpm at the same speed. Since inertia forces of the reciprocating and rotating parts vary as the square of the speed (rpm), they are reduced 45 per cent at 60 mph and even more at higher car speeds. That is why at these low engine speeds, engine smoothness and quietness are noticeably enhanced.

Advantages accruing to the automobile field as a result of the contribution of Dual Range Hydra-Matic thus include improved performance, less engine friction (and, hence, improved fuel economy), better engine braking, and generally smoother, quieter, and more pleasant travel.

Conclusion

Similar progress stories could be offered on many other contributions of the Pontiac Motor Division to the advancement of automotive engineering. With improvement in products has gone the development of manufacturing techniques, which blend into a total picture of an engineering force constantly working toward improvement of motor cars and their production with least possible expenditure of manpower and materials.

Notes About Inventions and Inventors

Foreword

FROM theory, practice, invention, discovery, engineering, and research our patent system has encouraged invention and protected small industries and new developments in larger industries. A measure of the values created by engineering progress may be drawn from the exponentially rising curves marking progress toward an ever-increasing standard of living. For example, our efficiency in producing food has increased by a factor of over 500 per cent in a century: in 1850 85 per cent of our population lived on farms, now about 15 per cent.

Those who wrote into the Constitution the foundation of today's patent law put a premium on man's thinking power and its fruits. The first article says: "The Congress shall have power . . . to promote the progress of science by securing for limited times to inventors the exclusive right to their discoveries." The inventive mind through a thinking process *foresees* apparatus and usually a working model is completed to prove the validity of that foresight. We commonly think of a problem as solved by apparatus, but actually it is solved in a man's mind. Thinking precedes all intelligent action, and thinking is a free commodity. It is the one thing in this world upon which no one has ever been able to put a tax or tariff.

Granting of a patent begins a process rather than serving as an end. A patent ties the secure, protective cords of law around a package of thinking; but the cords may slip. Though a patent might build a tremendous business and find application by the millions, its value lives only until the evolutionary thinking process of man renders it obsolete. Fundamental physical truths defy change, but man's application of these truths obsolesces.

In reading "Notes About GM Inventions and Inventors" and the technical papers in the JOURNAL you will witness again part of the vast gains made in a sparse half-century of research and engineering. Reading about past and current accomplishments should not make us so proud that we relax our efforts. This really is the age of opportunities unlimited. We have chipped off only a fragment from the Mountain of Knowledge. The future is bright and it ought to be very important to each of us, for we will all spend the rest of our lives in it.

C. F. Kettering

Director and Research Consultant of General Motors Corporation

GENERAL MOTORS' leadership in industry is based in large measure on the ability of its engineers to develop new products and improved manufacturing methods and the willingness of its management to take the serious risks involved and make the heavy investments required to put them in production.

What company can match GM's pioneering? Think, for example, of C. F. Kettering's self-starter; Thomas Midgley's ethyl gas and Freon; C. E. Summers' harmonic balancer; E. A. Thompson's synchromesh and Hydra-Matic transmissions. While in these instances and many others some one man will always be associated with each development because of the importance of his part in it although many contributed; in others a number of ingenious engineers contributed almost equally. Consider, for example, the teams in our car Divisions that have given the Corporation undisputed world leadership in the automobile industry; the Kettering-Research team that developed our Diesel-electric locomotives and other Diesel power plants; the Frigidaire team that pioneered electrical refrigeration; the teams in many of our Divisions that have developed ingenious automatic manufacturing equipment that has saved millions of dollars; the Fisher teams that through many improvements in products and manufacture have led for many years in fine body manufacture, and the many teams in our parts and accessory Divisions that have set the pace for their competitors.

Nor is all the glamour surrounding invention confined to the famous inventors of the past—such as Howe, Morse, Goodyear, Edison, and Bell. What about the experimental engineer at one of our struggling young Divisions who, lacking money for experimentation, used his own cash to buy ten-cent-store equipment to see if he could develop a much needed new product. Eventually he succeeded. For this and other accomplishments demonstrating his initiative and ability to get things done he is now a Division

By GEORGE H. WILLITS
Director,
Patent Section

Everything worth inventing

has been invented?

Not so, records prove

ager and doing fine. What about the g engineer faced with failure of a uction process for which the Cor- tion had paid a great deal of money, conducted tests after hours on a ess in which he alone had confidence was his baby? He achieved success. s now a chief engineer in charge of lopment. Then there are the better vn stories about the heartaches in- ed in developing ethyl gas; about the el development team under Mr. ering's enthusiastic leadership that erted a luxury yacht into a labora- to develop new products to help is out of the depression; the round- clock pioneering by Earl Thompson his colleagues that resulted in the successful automatic transmission. hoped that in future issues some of stories can be told.

ntiveness Continues Upswing in 1953

he curves of Fig. 1 indicate that GM neers are keeping up in inventive- Patent applications are usually filed tly after the invention is made. The y falling off during the war years mething to be proud of because it is penalty suffered by management's sion that in the interests of the country commercial development must be bed for the duration. It takes some after the resumption of develop- t for inventions to be made and d and sent to the Patent Section. increase in patent applications since is very gratifying, particularly in of the national trend in the other ction.

any attribute this national trend to marked tendency of the courts to patents invalid. An outstanding nce is the Supreme Court's holding Marconi's invention of wireless was an obvious accomplishment and his patent invalid. In time the Courts are bound to become more realistic in appraising inventions, particularly those that form the basis of new industries as did the famous inventions of the past. In the meantime, whether patents are strong or weak GM must continue to lead in new developments for the sake of its customers, its employes, and its shareholders.

The curves of Fig. 2 show the total number of patents granted in the U. S. compared with the number granted to General Motors. It is usually three or four years after the filing of a patent application before a patent is granted. Hence the time lag between the patent application curves of Fig. 2.

Patent Knowledge Widespread

General Motors' patents are distinguished from the ordinary run in that almost all of them cover practical ideas. Our inventors know the practical possibilities in the fields in which they work. While many of our patents are taken out primarily to make a record of our commercial developments in highly competitive fields where others are patenting every improvement, however slight, there are many others that are of considerable importance in protecting our latest products from being copied.

No one in the United States has done as much as our own Mr. Kettering in encouraging new developments and in demonstrating by his own inventive ability and enthusiasm how they can be made and carried through the shirt-losing stage to become tremendous successes. Our development program is now being expanded far beyond anything the Corporation has ever done before. Consequently the opportunities in General Motors for engineers who can produce well-thought-out ideas for future improvements and future products is greater than ever. Whatever may be its economic strength, a patent is, as Mr. Kettering has often said, an order of merit granted by our Government to men with imagination and an eye to the future.

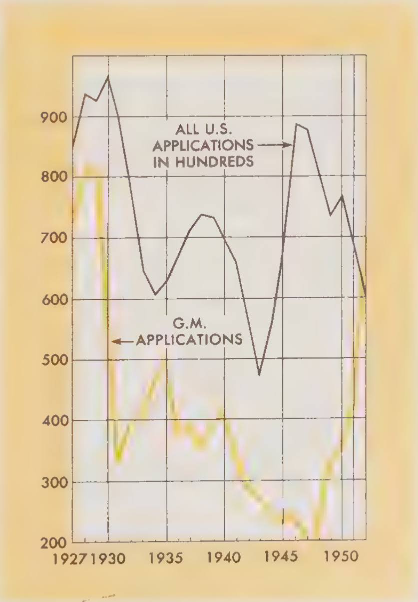


Fig. 1 — Curve of GM applications currently rising as national curve falls.

January Brings 27 Patents

Twenty-seven patents were granted in January 1953 to General Motors inventors. Typical of these inventions are the following 11:

James S. Burge, Hilton J. McKee, and Richard M. Goodwin, *Delco-Remy Division, for a Machine for Making Electrical Coils, No. 2,624,374, issued January 6.* The invention relates to the manufacture of electrical coils. One of the many features of the machine described in the patent is a mechanism which applies tape to the wound coil before it is removed from the form, thus insuring that the coil retains correct shape.

Mr. McKee serves as an engineer in the Process Department of Delco-Remy Division, where he was originally employed in December 1942. He is a 1932 graduate of Ball State Teachers College and has spent most of his career on design of electrical machinery.

Mr. Goodwin is a senior machine designer in the Process Department of Delco-Remy Division, where he has been employed since joining in September

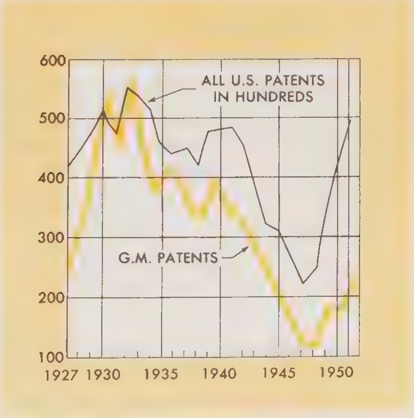


Fig. 2—GM patents issued continue increase after war-caused low in 1948.

1937 as a designer. Mr. Goodwin earned the B.S.M.E. degree from Purdue University in 1932.

Mr. Burge is no longer with the Division.

Paul E. Clingman, *Inland Manufacturing Division, Dayton, Ohio, for a Crash Panel for Vehicles, No. 2,624,596, issued January 6.* The patent describes a crash panel for use in connection with automotive vehicle dashboards. The panel is of approximate C-shape and is easily attachable. Being resilient, the panel absorbs shock and reduces the chance of injury.

Mr. Clingman serves as supervisor of Quality and Control at Inland. He joined the Division in December 1930 as an assembler and earned the B.I.E. degree as a cooperative General Motors Institute student from 1931 to 1935. He was promoted to foreman in November 1936, tool coordinator in January 1941, assistant war projects coordinator in January 1944, assistant to the chief engineer in December 1945, and to his present position in January 1953. This is one of five patents resulting from Mr. Clingman's work in the field of automotive bodies.

William T. Mears, *Guide Lamp Division, Anderson, Indiana, for a Socket Connector Having Removable Terminals, No. 2,624,773, issued January 6.* The invention relates to a connector for sealed beam lamps and comprises an insulator having passages in each of which is locked an electrical connector in the form of a spring clip which engages both the lamp terminal and the terminal on the conductor supplying current.

Mr. Mears serves as an experimental engineer in the Engineering Department of Guide Lamp Division, where he has been employed since joining in June 1928 as a tool maker. This is the fifth patent resulting from his laboratory work, which has included several years as a foreman in the model shop.

William E. Brill, *Cleveland Diesel Engine Division, for a Power Plant, No. 2,625,145, issued January 13.* The patent covers certain features of the Cleveland Diesel Model 338 multi-row, vertical, radial, Diesel engine, combined with an electrical generator as a unit. The features include a barrel-shaped crankcase consisting of a number of individual steel forgings which are welded together. The complete crankshaft assembly, including main bearings and main bearing carriers, is inserted through the top opening into the crankcase. The cylinders are seated in the barrel forging and outer deck forging of the crankcase. This arrangement facilitates assembly of the piston and connecting rods. The timing gear assembly is located at the bottom of the crankcase.

Mr. Brill has been an engineer at Cleveland Diesel since April 1933, and since April 1937, an assistant chief engineer. He earned his engineering degree in 1925 at Case Institute of Technology and has spent most of his career on Diesel engines, in which field his work has resulted in several previous patents. Mr. Brill has been active in the Society of Automotive Engineers and in the American Society of Mechanical Engineers.

Arthur F. Underwood, *Research Laboratories Division, Detroit, for a Bearing Lubrication method, No. 2,625,448, issued January 13.* The patent describes a method and means for lubricating bearings and journals subjected to loadings having a varying direction, such as wristpin bushings. Oil under pressure is supplied to circumferentially extending oil grooves adjacent each end of the bearing in the face which contacts the journal. It was found that to keep the oil film intact, the grooves must have a combined volume equal to the volume of the clearance space between the bearing and the journal but not greater than ten times this clearance volume.

Mr. Underwood serves as head of Mechanical Development Department, and this patent is one of 11 which his work on bearings and lubrication and automotive heaters has been instrumental in bringing to GM since he joined the Division in 1928. His writings in these fields have been widely published. Mr. Underwood came to GM from Massachusetts Institute of Technology, where he served as a mechanical engineering instructor while earning the master's degree in this field. His undergraduate B.S.M.E. also was from M.I.T., in 1926.

Stanley R. Prance and Harold J. Rei
Inland Manufacturing Division, Dayton O
for a Method of Conditioning Brighe
Baths, No. 2,625,468, issued January
This patent deals with a method for
ditioning chemical brightening b
such as are used for brightening
surface of aluminum parts and is
ticularly directed to the type of
which includes nitrate, fluoride,
ammonium ions. The method consis
removing specific portions of the
after treatment in it of a predeterm
area of aluminum and replenishmen
a like quantity of fresh bath for m
taining the efficiency of the ov
brightening operation at a substant
constant level.

Mr. Prance has served since May
as chief metallurgist of Inland's E
neering Department and super
metallurgical development, enginee
and purchasing specifications, pro
tive and non-productive metallic m
rials and processes, and metal finis
Before transferring to Inland he se
three years in the Research Laborat
Division, Detroit, as head of the
Chemical Section. This is the fo
patent in the fields of metal finis
organic finishing, and electro-pol
resulting from Mr. Prance's re
work. Mr. Prance also has written
on electro-polishing topics. A 1926
lurgy and metallography gradua
Wayne University, he is a member
Society of Automotive Engineers, A
ican Standards Association, Amer
Society for Metals, and the Materia
Processes Committee of the Gen
Motors Production Engineering Sec

Mr. Reindl has served since Jan
1952 as assistant chief metallurgi
Inland's Engineering Laboratory. U
receiving the B. Ch. E. degree from
University of Dayton in 1942,
Reindl joined Inland as a junior m
lurgist. This is the second patent resu
from his work in the field of m
finishing. As a student, Mr. Reindl
elected to Alpha Sigma Tau hono
society. He is currently affiliated wit
American Society for Metals and
Southern Ohio Rubber Group.

Joseph F. Schmidt, *Linden, N. J., P*
Buick-Oldsmobile-Pontiac Assembly Div
for a Welding Control, No. 2,625,651, i
January 13. The patent describ

rol system for welding machines can be quickly adjusted to provide erent time periods for the various ses of the welding cycle to permit ling of different materials or different knesses of material.

Ir. Schmidt serves as an electrical ntenance foreman in the Linden nt of Buick-Oldsmobile-Pontiac Asbly Division, which he joined in il 1937 as a welder maintenance man electrician. Mr. Schmidt successfully inated and developed air solenoid acers used on spot welding guns and ow at work on the improvement of welding tools.

larence H. Jorgensen, Willard T. kel, Howard H. Dietrich, and Donald Worden, *Rochester Products Division, ester, N. Y., for a Control for Multiple ines, No. 2,625,834, issued January 20.* patent describes a method and means controlling collectively and individ- the speeds of multiple engines of raft. Individual control levers act ugh a detent-sector arrangement to nchro-transmitter and receiver. The r control the circuits of a reversible tric motor which in turn operates a d controlling element of the engine.

Ir. Jorgensen has served since Novem- 1944 as chief research engineer of the earch and New Product Develop- t Department, Rochester Products sion. He is widely recognized as ntor of the automatic choke now on most GM cars. He began his eral Motors engineering career in 1932 as a development engineer in Engineering Department of Delco- ly Division. Mr. Jorgensen's research in automotive, aircraft, domestic, industrial appliances has made him rolific inventor. He studied at the versity of Wisconsin and the Uni- ity of Michigan, and is a member of Society of Automotive Engineers.

Ir. Nickel serves as a project engineer he Engineering Department of hester Products Division, where he is narily concerned with jet engine rols. He joined the Engineering artment of Buick Motor Division, t, as a layout man in October 1922, was promoted to product study man 938. In August 1939 he was transferred to Allison Division, Indianapolis, as an installation engineer for automatic controls, and he assumed his present position at Rochester Products in March 1945. Mr. Nickel's work has resulted in several patent applications.

Mr. Dietrich serves in the Engineering Department of Rochester Products Division, where he deals with new devices, project analysis, and patents. He is currently engaged in the study of aircraft engine fuel controls and carburetion, in which fields he has been granted approximately 25 patents. In 1926, Mr. Dietrich received the B.S.E.E. degree from Purdue University, where he was elected to Theta Tau and Kappa Phi Sigma honorary societies. Prior to joining Rochester Products in January 1946, he attended Yale University for special activity work. His technical affiliations include membership in the Society of Automotive Engineers and the American Institute of Electrical Engineers.

Mr. Worden has served since April 1951 as process engineer in charge of the Tubing Process Development Department, Rochester Products Division. He joined Rochester Products in April 1940 as a pipe fitter's helper in the Maintenance Department. He was transferred to the Electrical Department in September 1942, and to his present Department in October 1945. Mr. Worden has been granted one other patent in the field of electrical devices. He is affiliated with the American Institute of Electrical Engineers.

Edward P. Harris and Frederick W. Sampson, *Inland Manufacturing Division, Dayton, Ohio, for an Apparatus for Making Flexible Hose, No. 2,625,979, issued January 20.* This patent relates to an apparatus for forming continuously a flexible hose such as is used in defroster applications and the like, and comprises a machine for manufacturing such hose from tape material. The tape has an adhesive coating and is spirally wrapped with a reinforcing wire included therein to form the hose. It operates without the usual supporting mandrel and therefore hose may be made in any desired length. This is accomplished through use of a rotating stub mandrel formed from several peripherally spaced rollers having an outer diameter substantially equal to the desired diameter of the hose to be formed and cooperating with three permanently mounted larger rollers. The tape and wire are wrapped upon the stub mandrel and are integrated by the larger rollers whereupon the assembly is removed from the mandrel and cured.

Mr. Harris serves as a project engineer in Inland's Engineering Department, and is concerned mainly with foam door seals and car air conditioning. He joined Inland in August 1931 as a student in training. From 1938 to 1942 he was technical supervisor at the Inland Clark Plant and from 1942 to 1945, a laboratory supervisor at Eastern Aircraft, a part of General Motors during World War II. Prior to returning to Inland Manufacturing, he was employed at Detroit Transmission Division for a year. Mr. Harris received the B.S.M.E. degree from Cornell University in 1931. This is the fourth patent resulting from his laboratory work. His technical affiliations include membership in the Society of Automotive Engineers and The American Society for Metals.

Mr. Sampson is chief engineer at Inland, and is currently primarily engaged in developing rubber and metal combinations, such as ice cube freezing trays and plastics. He joined Inland Manufacturing as an assistant chief engineer in August 1929, and was appointed chief engineer in January 1942. Forty-two patents have been issued in his name in the fields of automotive parts, ice cube freezing trays, and fire arms. He is a 1924 graduate of Cornell University in the field of mechanical engineering, and is currently affiliated with the Society of Automotive Engineers.

James E. Jacobs, *Frigidaire Division, for a Snap Acting Fluid Motor, No. 2,626,183, issued January 20.* The patent describes a fluid pressure operated control means such as may be used for temperatures and pressure control work. The device incorporates a fluid motor in the form of a metal bellows which has its open end sealed to a valve seat structure which is adjustably supported by the frame. A double acting valve is provided in the seat structure and connected to the bellows. One valve seat opening communicates directly within the bellows while the second opening connects to a thermostatic fluid pressure element.

Externally the bellows may be connected to any suitable control device such as a switch or a valve mounted upon the frame.

Mr. Jacobs serves as a section engineer in the Engineering Department of Frigidaire Division, where he is currently primarily engaged in the development of electric controls for refrigeration and automobile air conditioning. Since joining the Frigidaire Patent Department as a draftsman in February 1937, Mr. Jacobs has progressed to tracer in July 1941, to layout man in March 1943, to project engineer in April 1946, to senior project engineer in October 1950, and to his present position in March 1953. This is the 18th patent in the fields of refrigeration and appliances issued in his name. He is studying for the B.S.M.E. degree from the University of Dayton and will graduate in 1954.

Marshall C. Harrold, *Frigidaire Division, for an Electrical Apparatus, No. 2,626,330, issued January 20.* The patent describes a means for protecting an electric circuit from overload with a device which cannot by any possible manipulation short of actual destruction be prevented from carrying out its protective function. The device incorporates a contact breaker which is rockably mounted on a slide member normally held in closed position by an electro-thermally responsive ratchet wheel. Upon release of the ratchet wheel, the spring moves the contact breaker into engagement with a stop means. The reaction from this engagement pivots the contact breaker to open circuit position.

Mr. Harrold serves as a senior project engineer in the Engineering Department of Frigidaire Division. Upon receiving the B.S.M.E. degree from Purdue University in 1931, he joined the Personnel Department of Frigidaire as a student trainee, progressing to junior tester in June 1932, junior engineer in December 1939, and to his present job in July 1942. His work in the field of electric controls has resulted in four previous patents. Mr. Harrold was elected to Pi Tau Sigma and Tau Beta Pi honorary societies at Purdue University and is affiliated with the Dayton Engineers Club.

Other January patents, of equivalent nature to those described more fully, are as follows, with the inventor's Division shown as of the time when applications were made:

Robert O. Scofield and Herbert C. Schryver, *Packard Electric Division, Warren, Ohio, for a Stator Winding Machine, No. 2,624,518, issued January 6.*

Earle S. MacPherson, *Chevrolet Division, for a Vehicle Wheel Suspension System, No. 2,624,592, issued January 6.*

R. K. Shewmon, *Delco Products Division, Dayton, Ohio, for a Switch Locator, No. 2,624,814, issued January 6.*

Oliver K. Kelley, *of the Central Office Engineering Staff at the Technical Center, just north of Detroit, for a Fluid Drive and Controls, No. 2,625,056, issued January 13.*

K. Clark, *Frigidaire Division, Dayton, Ohio, for a Centrifugal Washing Machine, No. 2,625,809, issued January 20.*

K. L. Berninger and J. F. Haines, *Aeroproducts Division, Dayton, Ohio, for a Propeller Mechanism, No. 2,625,998, issued January 20.*

T. A. Olson, *Hyatt Bearings Division, Harrison, New Jersey, for a Honing Device, No. 2,626,486, issued January 27.*

DeLoss D. Wallace and W. F. Erickson, *Moraine Products Division, Dayton, Ohio, for a Hydraulic Pump and Motor Power Supply, No. 2,626,503, issued January 27.*

L. J. Lamm, *Patent Section, Central Office Staff, Detroit, for Electrostatic Spray Painting Apparatus, No. 2,626,589, issued January 27.*

K. L. Berninger and J. F. Haines, *Aeroproducts Division, Dayton, Ohio, for a Propeller Mechanism, No. 2,626,668, issued January 27.*

R. E. Moore and J. F. Mack, *Aeroproducts Division, Dayton, Ohio, for a Propeller Control, No. 2,626,669, issued January 27.*

R. E. Moore, *Aeroproducts Division, Dayton, Ohio, for a Propeller Control, No. 2,626,670, issued January 27.*

G. A. Brundrett, *Delco Products Division, Dayton, Ohio, for a Shock Absorber, No. 2,627,685, issued January 27.*

J. W. Lawson and W. E. Brown, *Delco-Remy Division, Anderson, Indiana, for a Switch Mounting, No. 2,627,006, issued January 27.*

If You Like Mathematics

"Mathematics and the sciences p vide an excellent background for h dreds of jobs in modern industry. Th are many technical positions which not require a complete engineering cou but which do involve problems wh mathematics and scientific analysis m be used. And even a salesman has to able to figure out his commission."

"Can I Be an Engineer?"
Department of Public Relations
General Motors

Industrial 'Lone Wolf' a Rarit

"Few indeed are the industrial p tions wherein an engineer can work a 'lone wolf.' If he honestly wishes to p gress, he must be able to adapt him to work with people until his respo bilities increase to such an extent t the major requirement is for people work with him."

Gordon, John F., Vice Presid General Motors. "Orienta and Development of Jun Engineers." *The Journal of gineering Education,* January 1

BTU's and Butterflies

"Throughout the entire life cyc the butterfly, it changes character t times. First, it is an inert egg. Then becomes a caterpillar with limited h zons. Finally, it matures as an u strained butterfly. During each stag its existence, so many days pass by and each transition from one stage i another takes so many days.

"Temperature has much the sa effect on ice as age on the butterfly. at 'birth' on the thermometer (which 459° below zero), will 'live' for BTU's as ice. Then, for the next BTU's of its 'life,' melts into water. T stage is known as the Latent Heat Fusion. For another 180 BTU's, wa 'grows up.' Finally, water 'ages' 970 BT at the boiling point while it changes i steam. This is the Latent Heat of Vapo zation and, from a refrigeration sta point, it is the stage where the m cooling is done because it involves greatest number of BTU's."

"A to Zero of Refrigeration"
Department of Public Relations
General Motors

)esign Problems of Combination ignal Seeking and 'ush Button Radio Receivers

By JAMES H. GUYTON
Delco
Radio
Division

How engineers built maximum tuning ease into a car radio

;nal Seeking radios which automatically and accurately tune in stations in frequency ıuence each time a starting bar is depressed have an established place in automobile eivers. Now this tuner has been combined with the more conventional push button ing. The resultant design provides the convenience of both systems of tuning and at same time features the accuracy of indexing inherent in the signal seeking system of ing. In addition, push buttons may be preset more easily than with standard mechanical h buttons. The designs of the mechanical and electrical components of this tuning tem necessarily must be closely coordinated, and integration of these designs constied a large portion of the development task.

UTOMOBILE radios are designed, of necessity, for very high quality. They ıst operate over extreme temperature ıges from short antennas and still pro-e a high level of sound output with a nimum of background noise. The tun- must not be jarred off station under rmal car bounces and the receiver must well shielded from the ignition system.

[t is well known in the radio art that proper tuning of a broadcast receiver ults in serious degradation of permance and tone quality, and it is to advantage of the listener to use all of quality built into his receiver by curately tuning each station.

Recognizing this situation, Delco Radio s provided the better auto sets over past few years with a signal seeking ner.[1] With this tuner, a push of a bar or tton starts the pointer moving across dial under its own power until a tion is encountered. When the station accurately tuned, the mechanism stops tomatically, and the next station may tuned in by another push of the butı. When the end of the dial is reached, solenoid quickly moves the pointer to low frequency end of the dial, and scanning process is repeated. If the tton is held down, the tuner continues scan until the button is released. A nt panel control can be used to adjust gain of the receiver during the scanıg cycle so that, if desired, only the onger signals are tuned in automatically.

With this tuner, the simplest possible ethod of tuning provides the highest ality of reception. This tuner is ideally apted to automobile receivers because the driver can quickly tune in whatever stations are available wherever he drives with a minimum of distraction from his driving. However, a great deal of field experience has shown that cars are often driven in one location for appreciable lengths of time between road trips. Under these conditions, it is sometimes desirable to provide push button tuning in addition to signal seeking tuning so that a few favorite local stations can be received by pushing buttons which have been preset to these dial positions.

Such a radio represents just about the ultimate in convenience and simplicity to tune accurately, and has been introduced in some 1953 model cars as factory installed equipment.

Basic Design

In approaching the problem of adding push buttons to a signal seeking receiver, it seemed logical to use the existing signal seeking mechanism and to arrange to have the push buttons make the system operative only over a small, preselectable portion of the dial. This makes maximum use of the tuning mechanism already provided and, in addition, retains the inherent signal seeking tuning accuracy when using push-buttons. In the resultant radio, a comparatively simple signal seeking tuner circuit was used.

Fig. 1 (top) is the second detector circuit of a high-quality commercial receiver with delayed bias in the AVC circuit. The components shown are normally used in all but the lowest cost auto radios. Fig. 1 also shows the extra components necessary to obtain a triggering or stopping voltage E_t, which appears just ahead of the point where a signal is tuned accurately. This voltage may then be used to signal the tuning mechanism to stop, and after a small coast, the tuner comes to rest, indexed on the signal. In this circuit, the grid of triode **T-1** is driven by RF voltage obtained from the secondary of the last intermediate frequency transformer. Tube **T-1** is biased past cut-off by the voltage drop V_1 across the cathode resistor. This voltage drop is obtained by "bleeding" current from a **+B** potential and may be of the order of 10 volts. In addition to this negative grid bias voltage, on strong signals, a voltage V_2 appears across resistor $\mathbf{R_2}$. This voltage is a portion of the normal delayed AVC voltage V_4 developed by the AVC diode $\mathbf{D_1}$. Of course, until the peak value of the IF voltage signal across the primary rises to a value of V_3, the AVC delay bias on $\mathbf{D_1}$, no voltage appears at V_2.

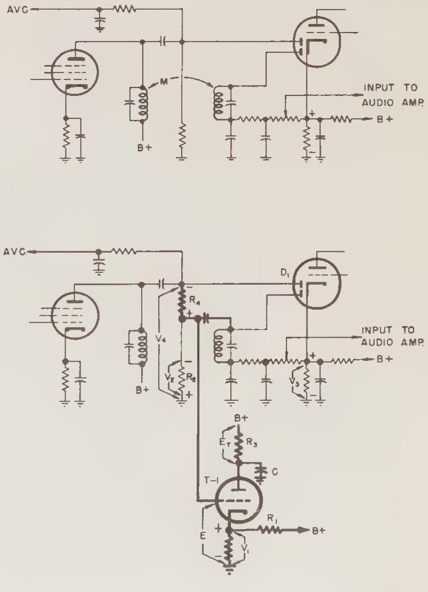


Fig. 1—A triggering or stopping voltage is developed in circuitry shown in bold lines. At top is a conventional second detector circuit.

yton, James H., "A Signal-Seeking Automobile Receiv- *Electronics*, Vol. 26, No. 5 (May 1953), pp. 154-158.

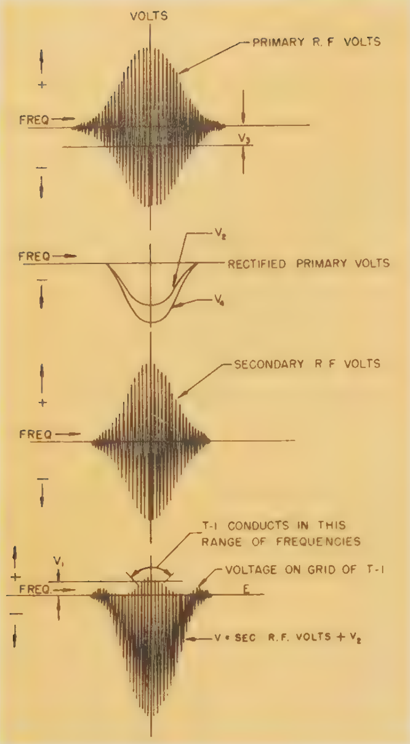


Fig. 2—Circuit control voltages of triggering or stopping circuitry plotted against changing radio dial frequency.

In the absence of signal, **T-1** does not conduct and capacitor **C** charges up to the **B** supply voltage to which $\mathbf{R_3}$ is connected. When a signal is encountered which is not strong enough to produce rectification in the AVC diode (no voltage at V_2) but which is strong enough near resonance to drive the grid of **T-1** into the plate conductive region, **T-1** discharges **C** for a portion of the RF cycle, and $\mathbf{R_3}$ charges **C** during the remainder of the cycle. The net result is that some average value of plate current flows in **R-3**, producing the voltage labeled E_t. As a weak station is tuned in, this voltage appears only very near resonance. The exact dial width in kilocycles over which E_t reaches an appreciable value is a function of the cathode bias on **T-1** and of the selectivity of the IF tuned circuits.

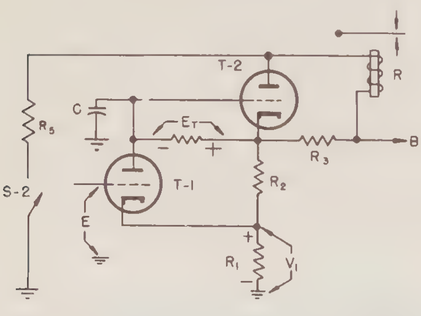


Fig. 3—Complete receiver triggering circuitry.

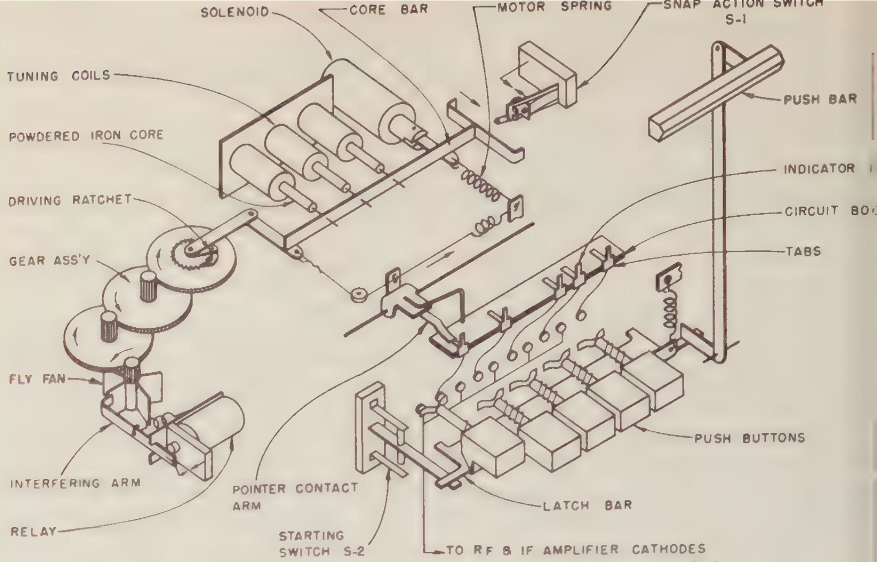


Fig. 4—Simplified sketch of mechanism for driving tuning cores and dial pointer.

On these weak signals, the selectivity can easily be made to be quite satisfactory for any IF system by adjusting the bias on **T-1**.

As the signal strength is increased, the dial width over which triggering voltage appears would increase to intolerable values without the action of the restraining voltage V_2. When the triggering circuit must accept stronger signals, the voltage V_2 improves the selectivity of E_t by adding an additional biasing voltage. By properly proportioning the resistors $\mathbf{R_4}$ and $\mathbf{R_2}$, the selectivity of E_t can be made as good on a very strong signal as on a weak one, and by this means, E_t may be provided with sufficient selectivity to stop the tuning drive, regardless of input signal strength.

In order for this circuit to operate properly, it is fairly apparent that as a signal is tuned in, the voltage V_2 must appear before the RF voltage on **T-1** has reached a high enough value to cause E_t to appear. This is another way of saying that the response curve of the RF voltage producing V_2 must be broader than the curve of RF voltage applied to the grid of **T-1**. If the standard practice of using double-tuned IF coils is followed, wherein each tuned circuit has approximately the same effective Q, the selectivity curve of voltage across the primary is unavoidably broader than that of the secondary. If excessive voltages at V_3 and V_1 are avoided, V_2 always appears as a station is tuned in before the RF voltage causes **T-1** to conduct, and is of sufficient value to prevent plate conduction of **T-1**, except in a region very near resonance.

The various RF and DC voltages described are shown in Fig. 2 and a identified by the nomenclature of Fig. Fig. 2 is not strictly correct because th RF voltages are shown as alternation plotted against a base labeled frequen rather than time. The presentation made in this manner because it clarifi the concept and quickly identifies th character of the various RF and D voltages.

The exact operation of the circuit complex. It can be shown mathema cally that if the efficiency of plate re fication in **T-1** is constant, regardless negative grid bias, the voltage divic action of $\mathbf{R_2}$ and $\mathbf{R_4}$ should be equal the IF transformer ratio for accura tuning at all signal levels. In practice, is found that as the total bias on **T-1** increased, and as the portion of the R cycle during which **T-1** conducts thereby decreased, the rectification eff ciency of **T-1** drops appreciably. Thu in practice, the voltage V_2 is a small percentage of V_4 than might be suspecte from a theoretical analysis. In practic the ratio of $\mathbf{R_2}/(\mathbf{R_1} + \mathbf{R_4})$, each resisto being given its ohmic value, ranges fro about 40 to 60 per cent of the transform ratio because of the inherent sharpenin effect of the plate rectifying efficiency **T-1**. The non-linearity of the i_p-e_g curv of the triode tube also causes propo tionately less drop across the resistor R on weak signals than on strong ones.

This inherent sharpening action of E is very helpful in quantity production these receivers. Because of it most of th components do not have to be held to th unusual tolerances which have heretofo been required.

The complete receiver triggering cir-
its are shown in Fig. 3. **T-2** is directly
upled to **T-1** with a relay in the plate
rcuit of **T-2**. E_t is thus applied directly
the grid of **T-2**. The tuning is started
momentarily closing switch **S-2**. This
ows current to flow through the relay
and the resistor R_5 to ground, thus
osing the relay and starting the tuner.
f course, while searching for a station,
2 conducts enough current through
lay **R** to hold it down. When the tuner
s tuned a station very close to reso-
nce, E_t appears, biases **T-2** to cut off,
d relay **R** drops its armature to stop
e tuning quickly. Fig. 3 also includes
circuit feature whereby bias on **T-1**
produced by relay current as well
bleeder current through R_3, R_2, and
. Once the relay current is reduced
tuning in a signal, the voltage V_1 is
duced, which causes an increase in
ltage E_t and further reduction of
lay current. The regenerative action
ntinues until the relay armature drop-
t point. This produces a positive snap-
pe relay action.

The Tuning Mechanism

The electrical tuning means in these
ceivers consists of three powdered iron
res moved in and out of three coils
ning the antenna RF and oscillator
rcuits in step. Fig. 4 is a simplified
etch of the power-driving mechanism
ed to move these cores and the dial
inter. In general design, this mech-
ism resembles a rugged Swiss music
x. The cores are driven by the motor
ring, and the spring force is also
ansmitted through the driving ratchet
d the step-up gear and pinion assem-
ies to the fly fan. This light nylon fly
n is loaded by air resistance propor-
nal to the square of its speed and is
fficiently large so that the cores are
illed across the band in about 4.5
conds. The mechanism is designed so
at only about 25 per cent of the spring
ll is used in overcoming friction of the
ars, cores, and bearings, and 75 per
nt is wasted in the fly fan vanes. Under
ese conditions, wide variations in fric-
on, lubrication, or bearing wear have
tle effect on the speed of tuning. Fric-
on high enough almost to stop the tuner
ll slow it down only about 25 per cent.
When the cores move to the end of
eir travel, a switch **S-1** is thrown by
e core bar; the solenoid is energized;
e cores are returned to the "in" posi-

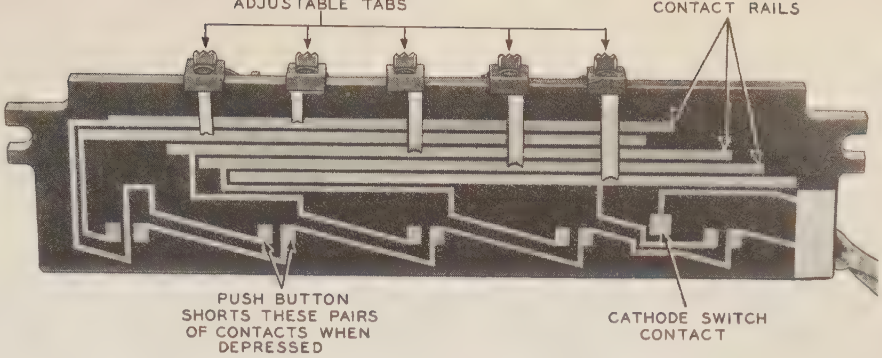


Fig. 5—Station selecting method features printed circuitry.

tion while the driving ratchet pawl slides around the driving ratchet; the switch shuts off the solenoid, and the scanning continues.

As shown in the diagram, the mechanism can be started and stopped by an interfering arm attached to the relay and extending to the fly fan. When the relay is energized, this arm is withdrawn and the tuner scans. When the relay is de-energized, the arm stops the fly fan. Since the gear ratio is designed so that approximately one kilocycle of core-bar travel is accomplished as one arm of the fly fan moves past the relay arm, the tuner is quickly stopped at the next one kilocycle point after the relay has dropped out. Since the fly fan assumes a heavy air load while running, most of the spring force is transmitted through the entire gear train whether the fly fan is operating or not, and backlash in the gearing is no problem.

This much of the mechanism has been used heretofore on signal seeking receivers. To add the push buttons, the bakelite circuit board is placed in the escutcheon assembly under the dial and is equipped with five indicator tabs adjustable from the front of the receiver. The push buttons are provided with switch contacts which remove the RF and IF amplifier cathode from their normal ground connection and connect them to the tab controlled by the particular push button selected. When a button is pushed, it is latched in the depressed position by the latch bar. The momentary downward movement of this bar caused by the cam surface on the push button selected releases any other buttons from the latched position and also momentarily closes the starting switch **S-2**. The tuner begins to scan the dial and, because the receiver is inoperative, no signal appears to stop the tuning until the grounded wiper contact attached to the pointer mechanism contacts the "live" tab. Over this short interval, the receiver signal seeks and accurately indexes on whatever station appears at this point on the dial.

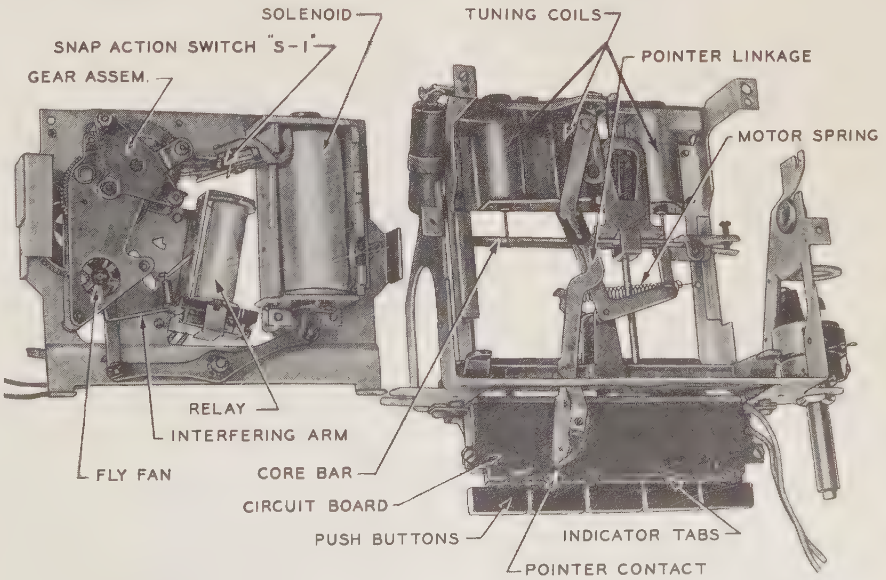


Fig. 6—Actual mechanism shown diagrammatically in Fig. 4.

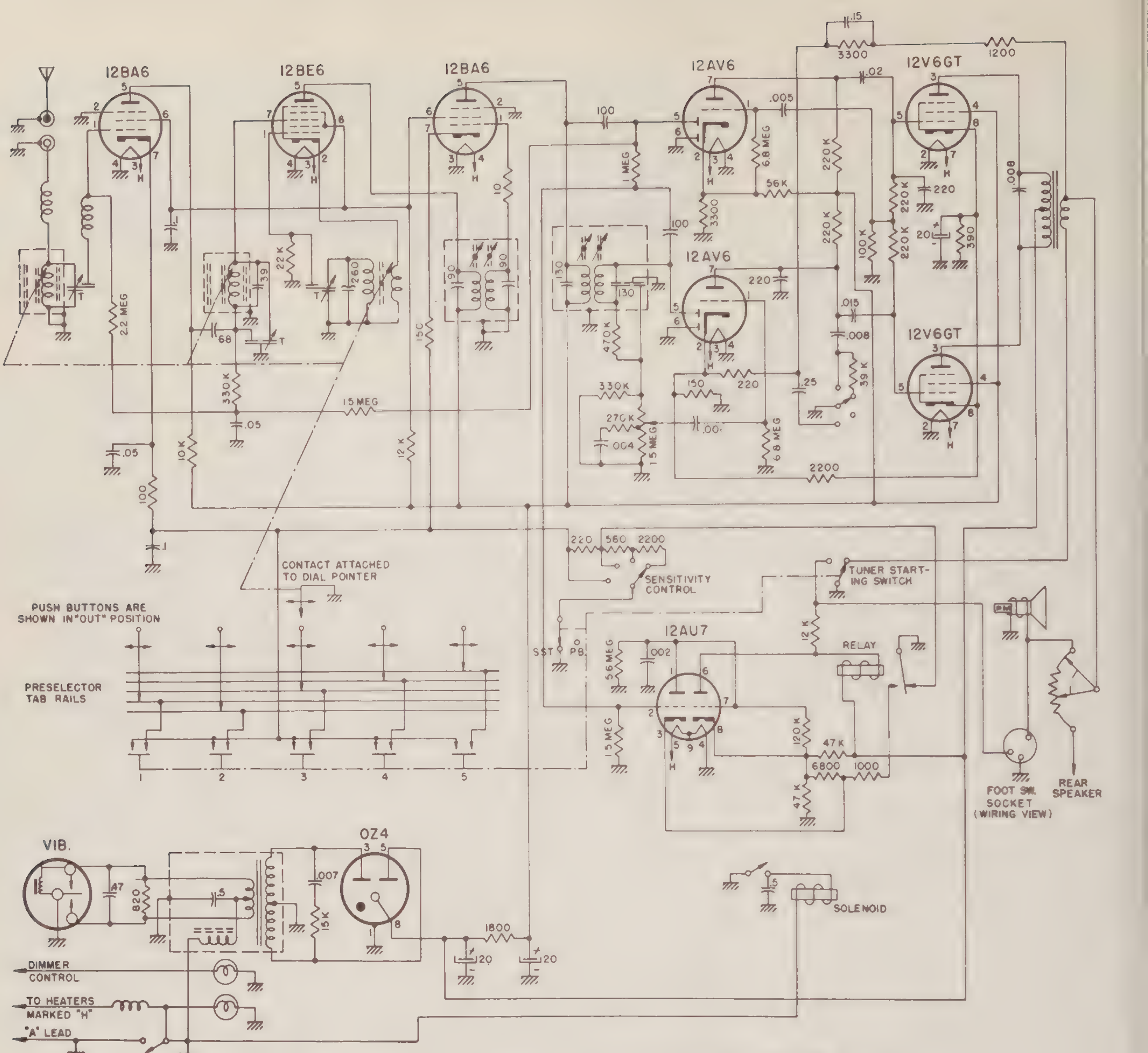


Fig. 7—Typical complete circuit diagram of favorite station, signal seeking radio receiver.

To signal seek with the receiver, the long push bar above the dial is depressed, and this action depresses the latch bar and closes starting switch S-1. These operations automatically unlatch any push buttons which may have been depressed and switch the cathode's circuit to ground through the sensitivity control.

Fig. 4 shows that a tab indicator point is opposite the dial pointer when the pointer contact arm is contacting the tab contact. To preset stations, these indicator points are placed under the pointer when the desired station is tuned in, and thereafter the receiver accurately tunes this station when the corresponding push button is depressed.

The rather complex switching requirement of the push button tuner portion of this receiver has been met in practice by the application of printed circuit techniques. Fig. 5 shows a view of the underside of the tab board showing the circuit connections and switch contacts which have been photographically printed on the surface of the board.

The tabs are shown in place, and it can be seen that connections from the five pairs of switch contacts are made through printed contact rails to the respective tabs. Of course, the contacts which engage the pointer contact arm are on the other side of this board. The cathode switch contact shown is grounded by a contact mounted on the push button latch bar only when all of the push buttons are unlatched, and the signal seeking sensitivity control is thereby thrown into the circuit. Simplicity of switching circuitry has been achieved to the extent that only two wires a required to connect this complete swit board into a standard signal seeki receiver chassis.

Fig. 6 illustrates the actual mechanis shown diagrammatically in Fig. 4. T top and bottom halves are shown se arated so that the components are mo easily identified. The push bar for sign seeking is mounted in the escutcheon a is not shown. It is linked mechanica with the detent bar and starting swit located under the tab board. The point mechanism is a straight line mechani linkage instead of the string drive Fig. 4, and the fly-fan gear train is o differential planetary type so that manual drive may be added if desir without rotating the fly fan when tuni manually. A second motor spring is us

remove backlash from the pointer, and e solenoid drives the mechanism through ever instead of directly. Otherwise, the eration closely duplicates that of Fig. 4.

In the complete receiver, more elec- cal functions are provided than have en outlined above. These require more less straightforward engineering but e essential to good operation of the stem.

For example, the relay is equipped th two contacts in addition to the stop- ng arm. These two contacts have two nctions. The *down* contact is a trigger rcuit disabling contact. Once it is eased, the tuning can resume only by osing the starting switch momentarily draw current through the relay. Thus, e set does not tune in a new station if e one which has been selected tem- rarily fades. The *up* relay contact short- rcuits the gain control to make sure of gh receiver sensitivity while listening a station. When this front panel nsitivity control is turned for maximum sistance, the receiver gain is reduced ly while tuning automatically so that e signal seeker stops on strong signals ly.

Further, a voltage divider is provided the trigger circuit standby connection prevent exceeding the heater-cathode ltage rating of T-1 and T-2 when the lay ungrounds the cathode circuit of -1. Also, a resistor from the plate of T-1 ground provides T-2 with bias in the andby condition to prevent unnecessary ain on the power supply. Another ature is a back contact on the triggering starting switch S-2 for opening the ice coil circuit before the relay pulls own. This prevents an audible pop from e loudspeaker, due to starting transients.

Conclusion

The circuits and features described and number of others are incorporated in e final design, which is now in opera- on on several car models. The complete hematic drawing of a representative vorite station, signal seeking radio is own in Fig. 7. This, and others similar it, is an almost completely automatic, lf-tuning receiver providing good tone uality and low noise level that goes with nvarying accurate tuning. It is difficult conceive what more might be desired an automotive radio, but engineers ven today are looking for means to nprove the present product line.

The Men on the Boards

By ELLSWORTH A. KEHOE
Rochester
Products
Division

There is a trend during today's shortage of engineers for recent graduates to short-cut the drafting and design room. Expedient as this now may seem to industry, and opportunistic as it may look to the young engineer, by-passing this important career-development phase may be to the long-range detriment both of industry and of young engineers as well.

A true human equation?

$$\frac{\text{drafting}}{\text{engineer}} = \frac{\text{interning}}{\text{doctor}}$$

An engineering drawing is the graphic language by which designers and engineers convey to others their ideas and instructions for the making of tools and products and the building of machines and structures. Unlike an artist's pictorial representation of an object or structure, the engineering drawing does not always show the object or structure as it would appear to the eye; consequently, this drawing can only be read and understood by those trained in this graphical language.

Because it is the basic method upon which all designing and subsequent manufacture is based, every engineer must know how to make and read engineering drawings. It certainly is not a language to be learned only by the comparatively few draftsmen who will be professional writers of it, but rather it must be thoroughly understood by all who are connected with technical industry.

Any language, be it English, German, French, Latin, or any of the others, cannot be read and thoroughly understood without the ability to write it. Words read without an appreciation of their real meanings certainly cannot convey to the reader's mind what the writer intended. If, on the other hand, the word meaning is completely understood, there is no reason why those words cannot be arranged and associated with one and another to form phrases and sentences which convey ideas to others. It cannot be a one-way street.

So it is with the graphical language of the engineering drawing. It is virtually impossible for the engineer to be able to read without being able to write the language. It, also, must be a two-way street. There are those who believe that it is possible to read a drawing without being able to draw one. There are even some schools that offer courses in blueprint reading, presumably designed for mechanics. While these courses undoubtedly serve a useful purpose, and while it will be conceded that some people may be able to read a drawing without being able to draw one, it could well turn out to be a case of a little knowledge being a very dangerous thing. It is a situation in which no engineer can afford to place himself, since his is the responsibility for design and interpretation. To prepare himself for this responsibility, it would be desirable for the engineering student to take all the courses in mechanical drawing and descriptive geometry offered by his school, and to enter industry by way of the drafting room.

Classifications of Drafting Room Personnel

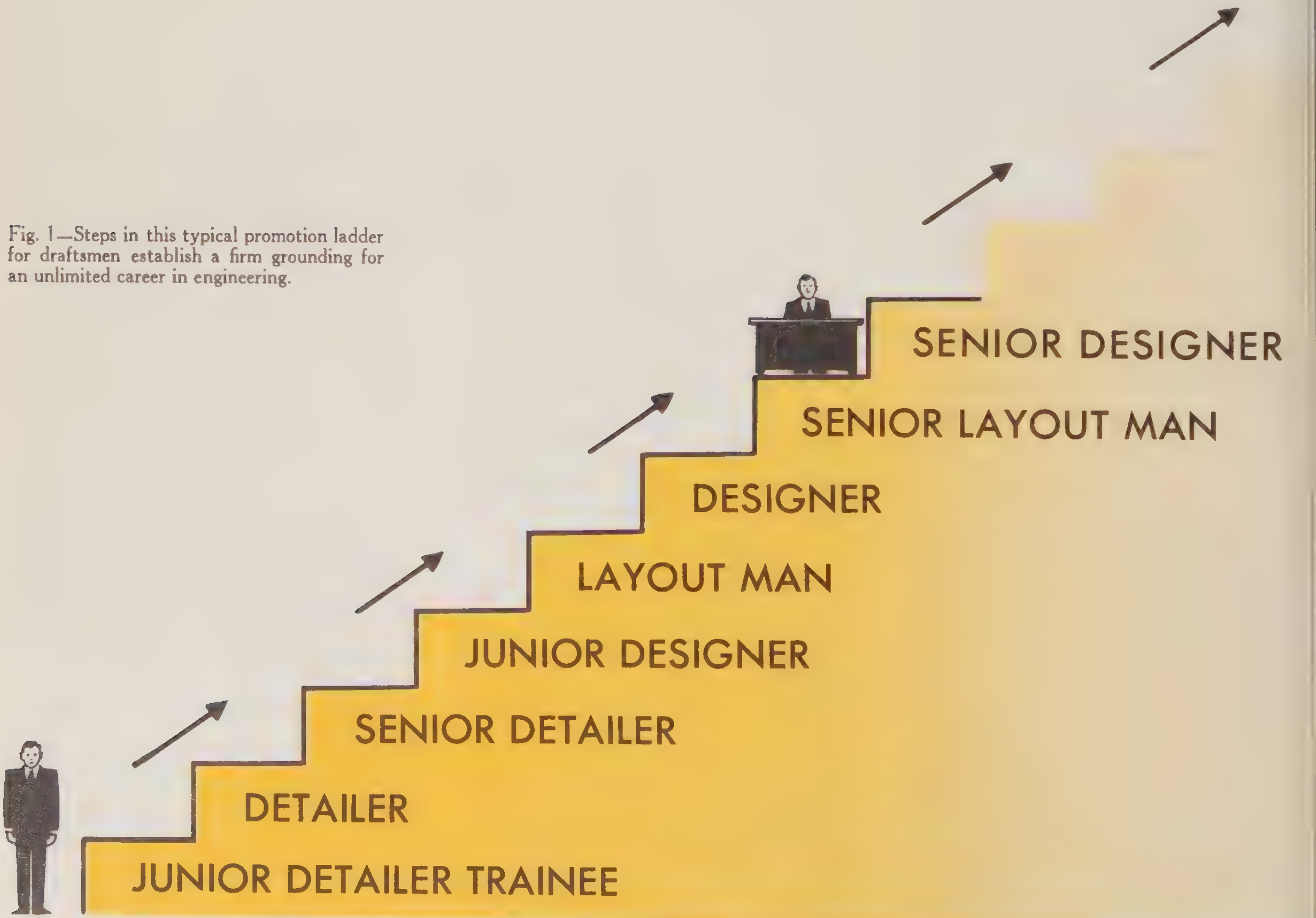
A good drafting room should probably be composed of four groups or classifications of people. One group may consist of men or women who have had little or no formal training, but because of a particular talent or liking for drafting have been brought in under some type of scheduled training program. Another group would consist of what may be called professional draftsmen. These are men who have chosen drafting as a profession and have prepared themselves for the profession by taking the prescribed courses in mechanical drawing, descriptive geometry, strength of materials,

mathematics, and mechanics at some technical school. These men are the backbone of the drafting room, the men upon whose shoulders rests the responsibility for putting into graphical language the ideas of the designer and the theoretical and practical solutions of the engineer. The third group may consist of graduate engineers who, initially, are much better equipped theoretically and technically than professional draftsmen, but would do the same type of work. It is this group, however, which may be expected to produce the greatest percentage of the fourth group, the designers. By this it is not meant to imply that the design group is beyond the reach of the men in the first two groups or classifications. There are no barriers to initiative and the acquisition of knowledge, and if a man from either of these first two groups displays the qualifications, he will most certainly be presented with the opportunity to become a designer.

Finally, it would be the design group which would create future design engineers. These are the men who, from training and experience, possess the knowledge and technique to develop the theory and tell others how to design the products of tomorrow. Because it is from here that all industry stems, it is the door to industry that offers the young graduate engineer the greatest opportunities for advancement.

Not too many years ago, when his services were not in such great demand as they are today, this was often the engineering graduate's only open door to industry. More recently, with the great shortage of engineering talent, industry has been forced to absorb youn engineers into their organizations with- out this basic post graduate training. While it is generally recognized that th procedure is not a desirable one fo either industry or the engineer, it ha been the lesser of two evils. An extende continuation of this procedure, however may result in industry being staffed wit engineers lacking one of the basic tool of the profession. The situation is analo- gous to eliminating the internship fro the requirements of the medical profes- sion. While at first the engineerin graduate may feel that he has eliminate a rather unimportant part of his trainin and has immediately been placed in position where he can use his talents t the best advantage, he may regret after few years his lack of this basic tool. H may even have the unfortunate experi

Fig. 1—Steps in this typical promotion ladder for draftsmen establish a firm grounding for an unlimited career in engineering.



nce of seeing younger men so equipped eadily approach and surpass him in osition and prestige. Therefore, it be- ooves both the engineering student and dustry to take a long hard look at this tuation; both have much to gain.

Theorizing upon and pointing out the isadvantages of shortcutting board work re desirable and necessary, but leave the tuation none-the-less existent. To this nd, most industries have instituted train- ng programs of one sort or another in the ope that they will bridge this gap in the rafting room. Actually, these training rograms and their administration have ecome one of the most important esponsibilities of management.

Operations of the Drafting Room

Perhaps a good way to describe a ypical drafting room would be to out- ne, in principle, how a trainee drafts- an and then a professional draftsman ould ultimately reach the status of a enior designer, a project engineer, or a osition of higher level in engineering Fig. 1). It is assumed that the prospec- ve trainee has had some training in echanical drafting of high school level r greater, together with a genuine nterest in this type of work. The training rogram as applied to the individual, of ourse, varies in detail depending upon he inherent ability of the trainee, his nterest, the extent to which he applies imself to the acquisition of technical nowledge, his ability to work with thers, and his personality characteristics.

Initially, the program should start with raining in the blueprint vault. This cquaints him with the sizes and use of racings, the filing and record systems, he operation of blueprint, and various racing reproduction equipment. These hings are all very important to the verall engineering department function ven though they may not be imme- iately apparent to the trainee.

The second part of the program should nclude training in the engineering records epartment. Here is where he acquires knowledge of the procedures and the ecessity for new product releases, new rawing releases, change requests, change otices, methods of part number assign- ents for both experimental and produc- on parts, and the distribution of prints various departments. This phase of he work represents the business methods hich are necessary to keep engineering ecords and to insure the prompt distribution of correct information to the various manufacturing and service departments of the company.

At the conclusion of these two preparatory periods, the trainee is assigned a drawing board and is given the opportunity to express ideas and instructions in the form of the engineering drawing. To begin with, the trainee's drawing assignments are strictly of an elementary nature, and he is constructively criticized by the checker and the chief draftsman.

As the trainee shows progress in his ability to make good elementary drawings accurately and quickly, he is given detail drawing assignments. This type of assignment involves progressively the drawing of simple and then complicated parts or groups of parts in assemblies.

Proficiency in this type of work leads to drawing assignments involving small layouts, and the trainee may be classified at this time as a junior layout man. It is at this time especially that he should be urged to acquire, either by himself or through formal training in night or correspondence school, a working knowledge of descriptive geometry, mathematics, strength of materials, mechanics, fabrication of materials, manufacturing methods, and machine and machine tool operations. This type of knowledge, whether it is applied to a product to be manufactured, a tool, or a structure, makes the difference between an ordinary design and a good design, and is a prerequisite to further advancement. If this knowledge is not acquired directly by academic study, it must be acquired by the slower method of mistakes and eventual corrections At this point in the trainee's career, his technical ability, his initiative, and his grasp of this method of engineering expression become increasingly apparent to the chief draftsman, the project engineers, and, in some cases, to the chief engineer. As he develops and acquires experience, the trainee becomes ready to assume the responsibilities of a senior layout man. It is at this point that the scheduled training program usually ends and the trainee is considered a professional draftsman.

The senior layout man has a wide opportunity to express originality and ability in design work, and the ultimate success of a manufactured product, a machine, or a structure is often determined on his drawing board. It is during this stage of his advancement that the draftsman becomes involved in engineering management within the drafting room. The degree of management varies, of course, with the individual, and is the result of a number of factors which have been established and evaluated during his employment.

The senior layout man may become a group leader and be responsible for the correctness and the application of the work of other men who are making detail drawings which form a part of an overall layout drawing. The senior layout man may become a checker, in which case he becomes responsible for the accuracy and adequacy of drawings to properly define the intended results. The senior layout man may become a junior and then a senior designer, in which case his talents may be used to collaborate with senior layout men and to work directly with the project engineers in starting new designs of products, or to create better and less costly methods and better and less costly designs of existing products.

The senior designer is the highest classification available to the draftsman, but instead of thinking of it as such, he should think of it as the ending of one phase and the beginning of another more promising phase of his career. It is his open door to opportunity and advancement to higher positions in engineering, manufacturing, inspection, sales or service, and eventually the management group of the company.

Conclusion

Draftsmen and designers are an essential part of our everyday existence. Every road, bridge, structure, machine, engine, household appliance, piece of furniture, piece of clothing, and practically everything else made for the use or comfort of man has at some time felt the influence of the draftsman. Moreover, as the universe and the natural laws that govern it become better understood, the man on the board becomes an ever more essential part of progress. Thus, any individual so engaged should view his personal efforts with pride in the realization that he is contributing his skill and services in a constructive manner for the benefit and advancement of society.

Acknowledgment

Acknowledgment is made to Mr. G. C. Porter, chief draftsman, and Mr. H. H. Dietrich, project engineer, for their valuable assistance in the preparation of this manuscript.

Development of the Cadillac Air Conditioner

Development by engineers of a new automotive feature often starts with the consumer's need. In the case of car air conditioning, Cadillac established first that the need and market existed. Then the Division drew up engineering criteria which the new product would have to meet. Solving the manifold engineering problems in fulfilling the specifications came next. In due time, the final production design was achieved. Throughout the development, thorough analytical and physical testing told engineers when sub-goals along the way were met. Current consumer demand indicates acceptance of car air conditioning.

On a particularly hot day in July 1952, car air conditioning came to an important milestone at the General Motors Proving Ground, at Milford, Michigan. There, Cadillac Motor Car Division test cars equipped with Frigidaire air conditioners performed with complete satisfaction in a final demonstration, and it was announced officially that GM engineers had perfected this new motor car accessory and that some 1953 models would offer it to the public.

Car air conditioning is available in 1953 models of Cadillacs, Buicks, and Oldsmobiles. This is Cadillac's report, and it is offered as typical of the engineering approach to many innovations in automobiles and seeks especially to show how the engineering phase is coordinated with other phases of the overall project.

The air-conditioning system and the experimental cars at Milford come late, chronologically, even in this story, which starts at a point when both cars and refrigeration had advanced to a high technological level along separate routes. This tells only how the two were successfully mated on the production line, and those at Milford knew that the achievement was announced only after many months of planning, testing, and development by many others besides engineers. These others included statisticians, sales and service, and production personnel of Frigidaire, Cadillac, and other GM Divisions.

Before Milford, chronologically, had occurred (a) a survey of customer demand and possible market, (b) establishment of engineering criteria which an air conditioner must meet, and (c) solving of engineering development problems. After Milford came achievement of the final design and the final solutions to tooling, assembly, and other manufacturing problems. This paper deals primarily with engineering solutions, but relates them to some of the vast contributions made during other phases of the project.

Survey of Customer Demand and Possible Market

The demand for an automotive air conditioner has come primarily from the United States' southwest, where air conditioning in homes and business places is considered a necessity rather than a luxury. Also, this demand has increased considerably in New York, Detroit, and other northern cities of more moderate temperatures where theaters, department stores, and office buildings have adopted air conditioning almost universally. As air conditioning itself advanced, Cadillac received an increasing number of letters requesting that a factory-designed air-conditioning system be made available.

In response to these requests, a joint survey was conducted by Frigidaire Marketing Department and General Motors Customer Research Staff to determine more accurately the magnitude of this demand and the potential market. The results of this survey made it clearly evident that a real need for car air conditioning existed. Particularly noteworthy were the facts that 50 per cent of Cadillac owners in the 25 southern states canvassed expressed decided interest in purchasing car air conditioning, and, of the cars in the Houston, San Antonio, Fort Worth, and Dallas area already equipped with car air conditioning, 92 per cent were Cadillacs.

The survey disclosed 14 reasons for liking an air-conditioned automobile other than comfort cooling. These can be grouped generally under quieter operation, cleaner driving, and less fatigue. Men in many occupations considered an air-conditioned car a business asset and a necessary luxury.

After the intensive survey, the project was undertaken and Cadillac and Frigidaire Divisions proceeded to establish performance criteria for car air conditioning, based on what consumers wanted.

Establishment of Ideal Requirements

The main components of an automobile air conditioner are the same as those of a household refrigeration or air conditioning system: refrigerant, compressor, condenser, liquid receiver, expansion valve, and evaporator.

The refrigerant used in the automobile air conditioner, as in most household systems, is Freon-12, a non-toxic, non-flammable, practically odorless gas having a boiling point of —21.6° F. Fig. 1 shows the relationship of the basic components. The refrigerant cycle may be traced, as follows:

> Freon gas under low pressure is drawn into the compressor, from which it is delivered, under high pressure and temperature, to the condenser. The cooling effect of the condenser reduces the gas temperature until it becomes a liquid under high pressure. This liquid then passes into the receiver which acts as a

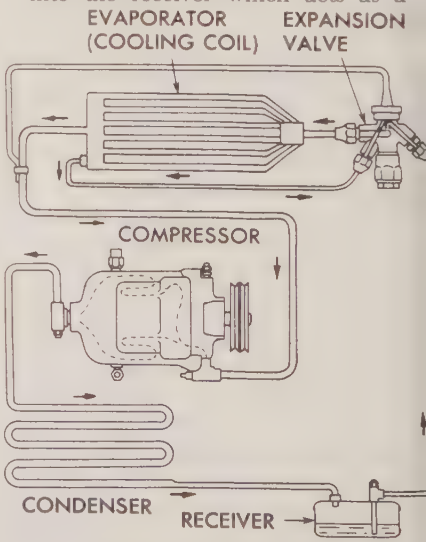


Fig. 1—Air-conditioning cycle of operation for full cooling.

By WEBSTER J. OWEN
Cadillac
Motor Car
Division

An engineering object lesson on producing a new car feature

reservoir, and from there to the expansion valve.

Due to the reduced pressure caused by the compressor, as the Freon leaves the expansion valve, the Freon enters the evaporator (which is the actual cooling unit) as a liquid under low pressure. Passage of warm car air over the evaporator causes the liquid Freon to boil and become again a gas. In changing from a liquid to a gas, the Freon-12 absorbs heat from the air passing through the evaporator, thereby cooling this air. The air then is discharged into the car. Then the low pressure Freon gas is drawn into the compressor again and the cycle repeats itself.

A car air conditioner equipped with he basic components listed above was nade available on Cadillacs in pre-war ars (Fig. 2). The experience gained in ustom-installing this system proved of alue. However, physical limitations reult from more modern automobile design nd greater glass areas. These necessitate nore cooling capacity than was available n the pre-war system.

Furthermore, much progress in air onditioning has been made in the past ew years. Consequently, it was decided o make an altogether new start in eveloping air conditioning for 1953 Cadillacs.

In order to become re-acquainted with ar air-conditioner problems, a test trip vas planned covering the southwest porion of the United States. Two cars were sed primarily, a Cadillac Engineering Division test car equipped with an air onditioning system already on the maret, and another Cadillac Engineering Division test car equipped with a Frigidire Division system embodying several ather recent departures from the conentional installations.

Principal features of the Frigidaire system were:

(a) Rotary compressor patterned after their Meter-Miser compressor used in home refrigerators, but designed especially for installation in automobiles.

(b) Magnetic clutch drive for the compressor to permit stepping up the compressor speed at low car speeds for greater capacity, and regulating compressor speed to a limited maximum at high car speeds.

(c) Air distribution ducts in the roof of the car for spreading cool air uniformly throughout the car. These differ from cool air delivery directly from the package shelf behind the rear seat.

These cars were equipped with pressure gauges and temperature measuring devices for test purposes. They were operated approximately 1,500 miles over a route providing both hot and humid weather, and hot and dry weather, as well as milder temperatures. Temperatures during this test trip ranged from 81° to 105°, and relative humidity from 23 per cent to 93 per cent.

Conclusions derived from the trip largely paralleled results of the customer survey and additionally established that satisfactory air conditioning is only partially due to reduction in temperature and humidity. Probably of as great importance is reduction of air noise and elimination of dust conditions and discomfort in general because windows can be kept closed. Another conclusion was that it is possible, by operating the system with automatic temperature control, to be very comfortable with windows closed in temperatures in the milder 70's, gaining maximum usefulness from the system.

Subsequently, the following performance goals were set up:

(a) Increase capacity to obtain at 20 mph car speeds cooling equal to that obtained in the original installation at speeds of 35 mph and more. Improved capacity had to be achieved by increased compressor output, increased condenser efficiency, improved car insulation, and better cold-air distribution.

(b) Improve engine cooling to make the road load and wide-open throttle cooling as good as that of the standard Cadillac without air conditioning and to improve idle cooling even beyond that of the standard car without air conditioning.

(c) Improve air distribution to increase diffusion of the original rear shelf cool air discharge and air velocity of the first duct installation.

(d) Develop effective means of temperature control to adapt it to a variety of weather conditions, varying from temperatures of 70° to over 100°.

(e) Eliminate odors and tobacco smoke and freshen car air by providing filters and introducing outside air.

(f) Conduct durability tests to insure meeting the rigid requirements of automotive use and Cadillac standards of quality.

The engine-cooling requirement was particularly important. In preliminary

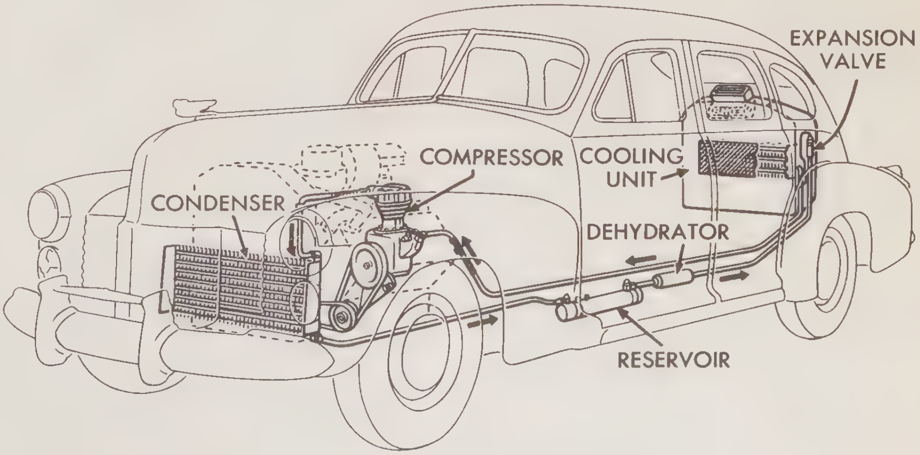


Fig. 2—Air conditioner in pre-war Cadillac.

tests, two automobiles, one with the original air conditioning installation and one standard car, were run at wide open throttle. The engine coolant in the car with air conditioning reached a given temperature on a day as much as 25° cooler than a day hot enough to raise the engine coolant in the standard car to the same given temperature. Idle cooling time at 100° ambient air temperature after an 80 mph road load run was also reduced to about 2 minutes in this first installation. This cooling was, of course, completely unsatisfactory being very much inferior to accepted practices on the standard car without air conditioning. It was determined that the wide open throttle cooling should be at least as good as that on the car without air conditioning and engine cooling at idle should be even better than that on the standard car. This is due to the fact that an air-conditioned car would be left idling to cool the car interior in hot weather.

Solving Engineering Problems

Once performance goals were established, analytical work in the laboratories was carried out toward achievement of each goal. Simultaneously, controlled tests were arranged to determine actual performance. Basic studies involved car insulation, air-conditioner capacity and compressor development, condenser design and engine cooling, automatic temperature control, compressor vibration, and air distribution.

Car Insulation

The first series of tests were set up to determine the effect of car insulation, on which subject many theories and opinions existed. Results of previous investigations were studied but were not accepted without complete testing. The test schedule was set up to cover insulation characteristics of the roof, dash, floor, protective baffles and other similar materials, sun visor, and E-Z-Eye glass. Tests were scheduled on the desert near Phoenix, Arizona, and the methods used proved rather more strenuous for testing personnel than had been expected.

Two cars of the same model and color were fitted out identically with means to measure temperatures at several points. Thermocouples were mounted to the metal at the dash and to the floor pan and at several locations on the roof. They also were mounted at the top of floor carpets directly over other thermocouples measuring metal temperatures, to insulation board on the interior of the dash wall directly over other thermocouples measuring metal temperatures at the same point. Headlining and breath level thermocouples determined temperatures directly beneath other thermocouples measuring roof metal temperatures. Others were spotted at various body interior points.

Care was taken to insure that the thermocouples remained fixed. For intance, the carpet and dash wall insulation board thermocouples were sewed in place so that direct contact to the surface was assured.

Immediate preparations for each test took considerable time and permitted the making of only one test per day. Since uniformity of conditions was desired, testing was done only on bright, sunshiny days of high temperature and with little wind. One car was maintained throughout as the standard baseline, and a preliminary run was made in each car with standard equipment so that variations between the two might be adjusted in results. Both cars were operated together each day with all temperatures recorded simultaneously. Thus, so far as possible, weather variations did not seriously affect test results.

Further efforts to insuring validity of results included taping of all windows and ventilation ports.

When both cars were ready, test personnel were instructed as follows:

(a) Park both cars in sun for two hours, recording temperatures every 15 minutes.

(b) Start up at 30 mph, both cars traveling together and running approximately one hour to stabilization of temperatures.

(c) Continue at 60 mph to stabilization.

(d) Continue at 80 mph to stabilization.

(e) Stop, turn off engine, park car for 45 minutes, recording temperatures every 15 minutes.

Test personnel consisted of a driver, temperature observer, and recorder in each car. With no ventilation and without benefit of refrigeration the cars heated up so that it was almost unbearable in the cars during a run, as ambient temperatures encountered were in the neighborhood of 90°. Breath levels reached 140° during parked conditions. A tank of oxygen for emergencies and two jugs of iced water were carried at all times. (Towels also were provided for absorbing perspiration, three towels per run.)

After the tests were completed, several important conclusions were reached. The basic conclusion was that *the primary heat load is directly from the sun*, and compared with this load, all other sources have little effect.

Other conclusions were: (a) any type of shade, such as a sun visor, is very beneficial; (b) E-Z-Eye glass, though mainly important for reduction of sun glare, has some benefit in reducing radiant heat; (c) roof insulation has no appreciable effect; (d) the dash insulation of the standard Cadillac proved excellent, being just as effective as when doubled in thickness, and (e) improvements in floor insulation were possible (and were made immediately on all Cadillacs, as discussed below).

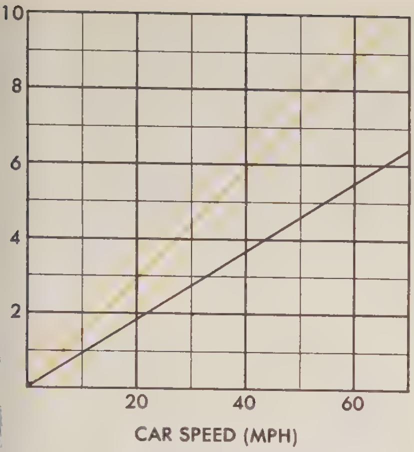
The finding on roof insulation was particularly interesting. While insulation is valuable for noise reduction and is necessary for winter conditions, roof insulation has little effect on the air-conditioning problem. Its effect either way, in preventing entrance of heat when parked or in preventing escape of heat when underway, is negligible.

Regarding dash insulation, it was found that positive sealing of all passages of under-hood air into the body and also the positive sealing of normal summer ventilation ports and other sealing were of far greater importance than attempting to modify insulation in any way.

On floor insulation, a basic change was made on all Cadillacs, regardless of air conditioning. Deadener paper was removed and the thickness of jute insulation on the floor pan was increased.

Air-Conditioner Capacity and Compressor Development

While the design of the first installation was carefully worked out and calculated for the known heat loads, insufficient attention had been given to the aforementioned radiant sun effect. Radiant sun effect is much more important in car air-conditioner design than in design for homes, railroads, and other more conventional services because of the relatively great area of glass in an automobile and because of the fact that the passenger frequently must sit directly in the sun's rays. Also, it is necessary to provide for extra cooling capacity in order to obtain



ig. 3—Upper curve shows how compressor pacity was improved for final design.

atisfactory initial cool-down. Consequently, previous calculations were permanently discarded. A trial period was itiated for the purpose of setting a cool-own period goal, based on comparisons ith the original installation.

Compressor capacity may be described terms of cubic ft. displacement per our. Using existing reciprocating compressors, it is necessary to limit the top peed of the compressor, thereby reducing the displacement per hour considerbly at lower car speeds. It was this esire for capacity at low car speed that rought about the selection of the rigidaire rotary-type compressor.

Frigidaire engineers stated that they ould design a rotary compressor of high isplacement which would be capable f operating at speeds twice that permitted in most ordinary reciprocating ompressors. Furthermore, a rotary compressor, because of its inherent precision onstruction and on account of the lack f necessity for compensating for unalanced forces of a reciprocating pump, ould be more easily balanced.

In order to determine the size and perating characteristics of the rotary ompressor, the results of the first investigation were used. These showed that e same capacity obtained on the first stallation at 35 mph car speed actually as needed at 20 mph.

In order to gain this greater capacity 20 mph, it was necessary to make a ompressor of large size (7.12 cu. in.) nd capable of operating at an engine peed ratio of 1.1 to 1. Many tests then ere run in the hot tunnel and under arious road conditions with this compressor design, mostly in the southwest ortion of the country.

Fig. 3 shows the compressor capacity obtained on the perfected design.

Condenser Design and Engine Cooling

The next major problem was that of engine cooling. This was a complicated problem because it also involved compressor design and car air-conditioner performance.

The original air-conditioner installation was very detrimental to engine cooling, as mentioned earlier. With throttles wide-open, the air-conditioned car's engine coolant reached a given temperature on a day 20° to 30° cooler than that needed to raise the coolant of the standard car to the same level. Also, when coming to idle after an 80 mph run at 100° air temperature, boiling occurred almost instantly.

The car with this installation was very much inferior to the standard car as far as engine cooling was concerned. It was necessary to make an air-conditioned car unusually good in idle cooling to provide air conditioning while parked.

Solving the problems required testing various types of condensers and other cooling system components for many months. During this time, the condenser

Fig. 4—Dynamometer testing in 100° F. ambient air showed that the original air conditioner installation adversely affected engine cooling both at 60 mph with wide open throttle and idling after an 80 mph run. The final air-conditioner car design resulted in engine cooling efficiency matching or exceeding the cooling performance of the 1953 standard Cadillac.

was changed from round tubes to flat tubes in order to increase the surface wiped by the air, and its depth was increased while the height was decreased. Also, the four-blade, engine cooling fan was replaced with a five-blade fan capable of higher air flows, and a ring was added around the fan for idle-cooling improvement. Finally, fan and water-pump speeds were increased to further improve low-speed and idle engine cooling as well as to improve air-conditioner operation by increasing condenser efficiency. The effect of these changes is shown in Fig. 4. Wide-open throttle cooling was improved by 26.6° and idle cooling was increased to more than seven times as good as that obtained in the original installation.

Automatic Temperature Control

The temperature control performance goal was to permit the use of the air conditioner through a very wide range of outside temperature conditions. In fact, it was found eventually that the air conditioner may be very successfully used to lower the breathing level temperatures even when it is necessary to employ the car heater for warming the floor. Thus, the air conditioner becomes useful in spring and fall as well as in the hot summer months.

Two types of temperature control were selected for investigation: a re-heat control employing a core similar to a car heater core to heat the air leaving the evaporator coils, and a thermostatic control connected to a solenoid by-pass valve, functioning when the temperature reached the setting desired.

It was possible with the re-heat control to obtain a very wide range of temperature control. However, there were disadvantages to this system, namely, (a) the danger of freezing water in the re-heat coil because of the low temperature of air leaving the evaporator coils, (b) the great degree of sensitivity required of the temperature control valve, and (c) the fact that the re-heat coil required valuable evaporator coil space, thus decreasing air-conditioner capacity.

The thermostatic control system proved much more practical in that it was easily installed. Its range, while not as great as that of the re-heat system, was more than sufficient, and it permitted use of a larger cooling coil in the evaporator. This system was adopted by Buick, Oldsmobile, and Cadillac although the

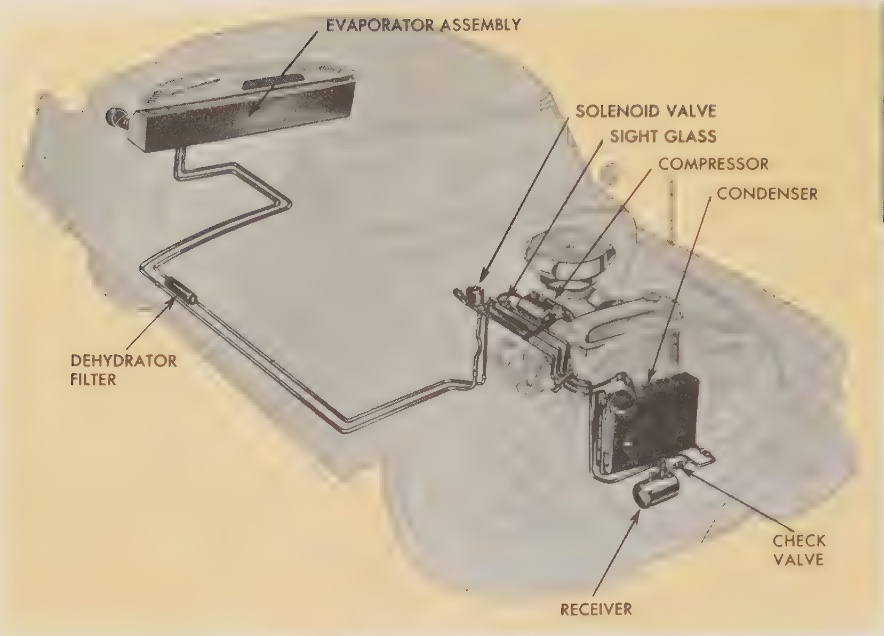


Fig. 5—An overall phantom view of air conditioner in 1953 Cadillac.

application varies somewhat in the installations.

Compressor Vibration

While the rotary compressor is, of course, much smoother than most reciprocating compressors, it became necessary to modify compressor mounting provisions to avoid a resonant vibration. Early attempts made included the use of a very rigid compressor mount and a very flexible rubber-type compressor mount. Neither of these was completely satisfactory and finally a rubber mounting, similar to the Cadillac engine mount, was developed. This consists of rubber-mounted bushings at the front end of the compressor and a rubber ring within a clamp at the rear end of the compressor. With this mounting, the vibration problem was satisfactorily eliminated.

Air Distribution

The preliminary survey disclosed that a very diffused air distribution through ducts maintained interior coolness in the most comfortable fashion and that the ordinary shelf discharge achieved quicker cool-down by increasing air velocities. For the production design, the most practical solution was determined to be ducts in the roof with controllable air outlets permitting the delivery of blasts of cold air directly to the interior of the car and also permitting the changing of these outlets to spread the air more evenly.

The principal problem here was to provide an installation attractive in appearance and permitting the delivery of the air from the rear package shelf to the roof duct. The final design uses ducts concealed beneath the headlining with movable outlet grilles. A clear plastic tube at each corner of the rear window delivers the air from the package shelf to the concealed roof ducts.

There was also a demand for a direct rear-shelf-panel discharge, and Cadillac decided to provide the two air delivery systems available at the customer's option on all sedan installations. The rear-shelf-panel discharge is employed on coupe installation.

Durability Tests

Like all parts of the car, the air conditioner was put through many final durability tests. Probably the most important of these tests involved equipping cars with air conditioning and sending them to various sections of the country to be operated by Cadillac and other General Motors personnel.

Field sales and service representatives in California, Texas, Tennessee, and Georgia used air-conditioned cars in covering their territories. Other cars operated in Arizona and, of course, many in and around Detroit.

To supplement the field operation, durability runs on the rugged Belgian Block Road at The General Motors Proving Ground at Milford tested Freon lines to determine the effectiveness of flared tube fittings and the proper location of flexible line connections.

Fig. 6—Evaporator unit is compactly packed i trunk, leaving a maximum of space for luggag and tire.

In addition to customary laborator durability tests of switches and othe components, special durability tests o the complete system were undertaken i the Cadillac Engineering Laboratory. I one installation, the complete car ai conditioner was operated with the car' engine running continuously at a constan speed equivalent to 97 mph. A singl failure on this test resulted in a redesig of the compressor discharge reed, an from then on the test ran without inter ruption.

The final laboratory test was made o a complete air-conditioner system con nected to an engine which was operate automatically to correspond to th General Motors Proving Ground *dura bility route*. In this installation, engin load conditions were automaticall changed, the transmission shifted fron neutral to first, second, and third, an also in reverse. Braking was applied and in fact, the entire route of 23 miles u and down hills at low and high speed over the durability route was duplicate in the laboratory. The route was travele over and over again until the equivalen of 25,000 miles had been covered. Ther were no air-conditioner failures on thi test.

Achievement of Final Design

And thus, after many months of plan ning, testing, and changing, the fina production design stage was reached Fig. 5 shows an overall phantom view o the air-conditioner system in the 195 Cadillac.

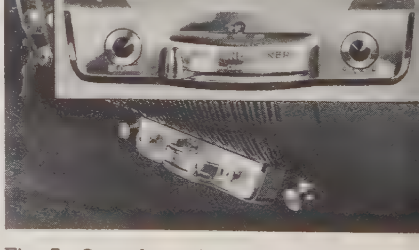


Fig. 7—Control panel is easily accessible an blends with dash styling. Inset shows thre control positions.

At the front, ahead of the radiator, is he condenser, and just below the con-enser is the liquid receiver. Attached to he engine on its special rubber insulated nounting is the rotary compressor. Near he compressor is a solenoid by-pass alve which by-passes the Freon around he evaporator when air conditioning is ot required.

Leading to the evaporator is the liquid ine equipped with a dehydrator for emoving any drops of moisture that night enter the system. In the trunk is he evaporator or cooling unit. Shown in his view are the two rear-shelf discharge rilles. The optional choice of roof ducts vith controllable outlets is not shown.

Also shown is the outside air scoop one is located on each side of the car) or delivering outside air into the car to reshen the car air. A large electrostatic ir filter located in the evaporator re-noves dust and also objectionable odors nd tobacco smoke.

Fig. 6 shows the installation of the vaporator in the trunk. Note the two arge blowers which provide an ample upply of cool air.

Fig. 7 is a view of the control panel. The master switch is provided with three ositions, OFF, ON, and VENT; in the ENT position, the blowers may be oper-ted to circulate the air in the car and to ntroduce outside air through the system vhen air circulation without refrigeration s desired. Each blower is operated ndependently to permit the delivery of large quantity of cooled air to the side n which the sun bears. The side in hadow needs a lesser flow of air.

The temperature control may be set s required. For maximum air condi-ioning, the temperature lever may be ushed to the coldest setting and both lowers turned to high speed. With roof uct installations, each passenger may urther adjust a roof outlet to direct air his face or wherever he may desire.

Conclusion

The entire program was a long and ften an arduous one. As with all auto-nobile features, research to develop uture refinements will continue. Further mphasis will most likely be placed on eduction of weight, design changes to acilitate installation, and other revisions improve the summer driving comfort. utomobile air conditioning is here to ay and it will receive increasing em-hasis in future fine car design.

Properties and Production of Aluminum Bearings

By ARTHUR R. SHAW
Moraine
Products
Division

New material promises six to ten times life of conventional bearings

Aluminum as a bearing material is not new, but the metal's expansion and bonding characteristics heretofore have been severe drawbacks. Using a new aluminum alloy developed by General Motors Research Division, engineers at Moraine Products Division developed a process which gave a strong ductile bond when this alloy was clad to steel. Further development led to applying a lead-base babbitt alloy, fortified with copper, as a protective alloy. Eventually, Moraine-400 bearing material tested to insure six to ten times the bearing life from conventional babbitt bearing materials, was evolved. Production facilities are now ready, and the new bearings may be expected to invite new advances in design of engines and other machinery.

MORAINE PRODUCTS has played an important role in the development of bearing materials for automotive engines. When engine output began to increase several years ago, it was demonstrated that conventional babbitt lined bearings rapidly failed due to fatiguing, and were inadequate to meet the demands of increasing loads and speeds. To meet the need of increased fatigue resistance, a new material known as Durex-100 was developed. This was accomplished by casting a lead base babbitt into and over a porous metallic matrix previously sintered to a steel backing and broaching the babbitt overlay to a very thin layer. The thin layer reduced the tendency to fatigue, and the matrix prevented the propagation of any fatigue cracks which developed. At the same time, the excellent conformability and embedability of babbitt were retained.

As engine output continued to rise, it became evident that bearing materials of even greater durability were required, and a research development program at Moraine was directed toward a bearing of maximum fatigue resistance and overall durability. Various babbitts were completely investigated and evaluated. It was found that although babbitt has no equal for anti-welding properties, its fatigue resistance could not be increased to a desirable level. By reducing the thickness of the babbitt to a thin film, the fatigue resistance was adequately increased, but its embedability and conformability was reduced to a point where the overall durability fell far short of the demands of highly stressed engines. It was, therefore, necessary to consider other bearing materials.

Aluminum As Bearing Material

Aluminum has long been considered as a possible bearing material, and the literature shows that bearings have been made of aluminum alloys over a considerable span of time. Because of the difficulty of bonding it to steel, all aluminum bearings had been of solid construction, and their performance had not been above reproach. It was not uncommon for such bearings to seize. One reason for their erratic performance was due to aluminum's high coefficient of thermal expansion compared to that of the steel connecting rod or cast-iron crankcase in which it was held. The aluminum would expand at elevated temperature and, being confined, the stresses exceeded its elastic limit. Upon cooling, the bearing became loose in its support allowing contact with the journal, which often interrupted the oil film. This same thermal property also caused an increase in bearing wall thickness at operating temperatures. This resulted in reduced running clearances which also tended to disrupt the oil film. Consequently, welding of the bearing to the shaft often occurred under extreme load operating conditions.

Fig. 1—Moraine-400 bearing.

An investigation showed that existing processes for bonding aluminum to steel resulted in a relatively heavy layer of brittle iron-aluminum alloy at the bond. These processes produce a material perfectly satisfactory for the purpose for which they were developed and used, but the brittle bond rendered the material unsatisfactory for engine bearing use because of its poor fatigue resistance, and the processes lacked adaptability to high production bearing manufacturing methods.

These processes did demonstrate that aluminum could be bonded to steel quite securely. It was felt that if a bearing were made by bonding a thin layer of aluminum to a steel-backing, the steel would control the aluminum expansion, keeping the bearing tight in its support. At the same time, by reducing the thickness of the aluminum, the tendency of the bearing wall thickness to increase would be reduced.

Aluminum-Clad Steel As Bearing Inserts

Accordingly, a series of development projects was started at Moraine to produce an aluminum-clad steel from which bearing inserts could be made. In the meantime, General Motors Research Division had developed an aluminum alloy bearing material which possessed excellent ductility and score-resistant properties.

The cladding of aluminum to steel was started with this alloy on the basis of very small samples of just a few inches in area. Development efforts eventually resulted in a process which gave a strong ductile bond, which is necessary to withstand fatiguing stresses imposed by engine bearing operation.

Following this development, early dynamometer tests were conducted with plain aluminum-clad steel bearings. Most of the test bearings ran exceptionally well, but occasional failures were encountered wherein the aluminum welded to the shaft in a manner which made the bonding process seem quite simple. It did indicate that in order to provide an additional safety factor, a babbitt overlay was necessary for improved anti-scoring properties.

Electro-co-deposition has an appeal from a production standpoint as a means for applying a lead-base babbitt alloy as a protective overlay. This was not a new art, but there was no experience to draw upon for applying it to aluminum, and to accomplish this, a second process development program was initiated. Numerous compositions and thicknesses were tested before the present combination was decided upon. This lead-base electro-deposit includes sufficient tin in its composition so that the babbitt is not subject to corrosion in the lubricants used in automotive engines. It was further strengthened by the addition of copper to the composition in order to give it sufficient strength and load carrying ability to enable it to operate satisfactorily in the heavily loaded modern engines.

The result of many years of development and dynamometer testing and several years of field testing has culminated in the present Moraine-400 bearing material (Fig. 1). A micro-section of this composite structure is shown in Fig. 2. Moraine-400 has resulted in a bearing which has very promising potentialities, offering from six to ten times the bearing life of the conventional babbitt bearing material.

Test Experience

In one of the engines used on dynamometer test, two sets of babbitt bearings are required in the life of one engine, while Moraine-400 bearings outlast three to four crankshafts and blocks. Heretofore, transplanting bearings from one engine to another usually resulted in early failures, particularly in the case of high-duty bearing materials which usually sacrifice adaptability for the greater strength necessary to support higher loads. That this is possible with Moraine-400 serves to illustrate the general adaptability and conformability of this bearing. In a General Motors conventional medium-duty truck engine, babbitt bearings usually run about 100 hours of endurance testing, while the Moraine-400 bearings have run 750 hours with ease.

The durability and long life of this material results from a combination of individual properties, such as anti-scoring, fatigue resistance, bond, embedability, conformability, corrosion resistance, and load-carrying ability. To date, there is no record of failure in engines which can be attributed to fatiguing or bond failure. There have been no failures from scoring where the bearings have been properly designed and installed. The embedability of Moraine-400 is fully equal to that of any bearing known and better than most. The conformability is also excellent, and is comparable to any bearing tested. Corrosion resistance is not a problem, since the babbitt used is highly resistant to corrosion, and the resistance of aluminum to corrosive attack is well known. The load-carrying ability is from four to six times greater than that of babbitt bearings currently used.

In attempting to determine the load-carrying ability of this material, several tests were conducted on the Oldsmobile V-8 engine. The rod bearing in the engine was chosen because there is no oil hole at the crown of the bearing to disrupt the oil film. In these tests, the bearing length was reduced to $\frac{5}{8}$ in. (Fig. 3) by counterboring the ends

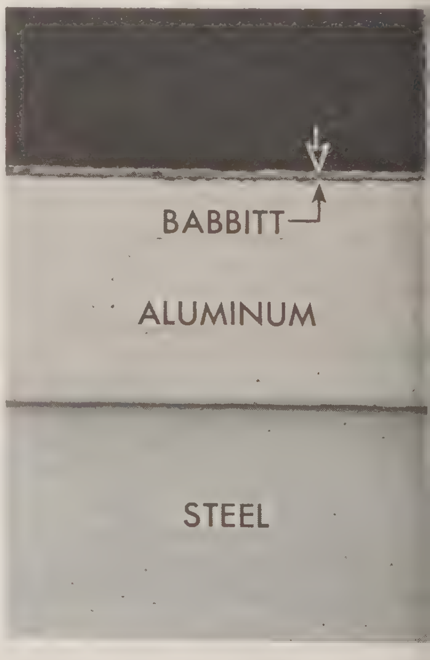
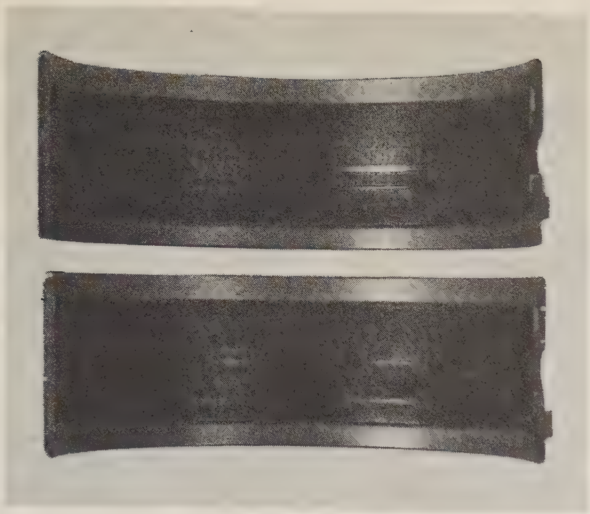
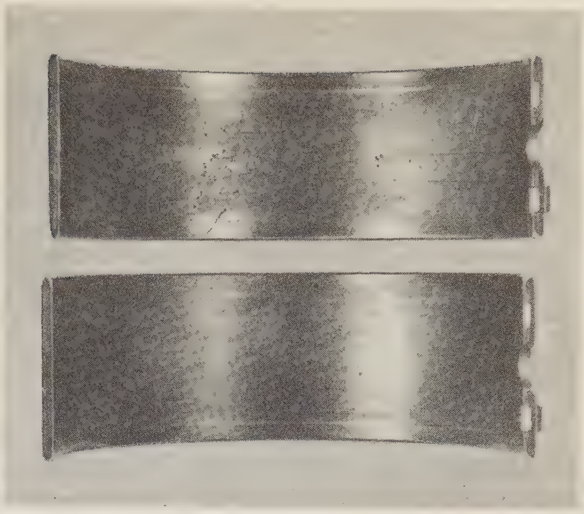


Fig. 2—Bearing material as seen through a microscope, enlarged 100 times. At the bottom is steel. This is clad with aluminum which is later plated with a thin layer of babbitt.





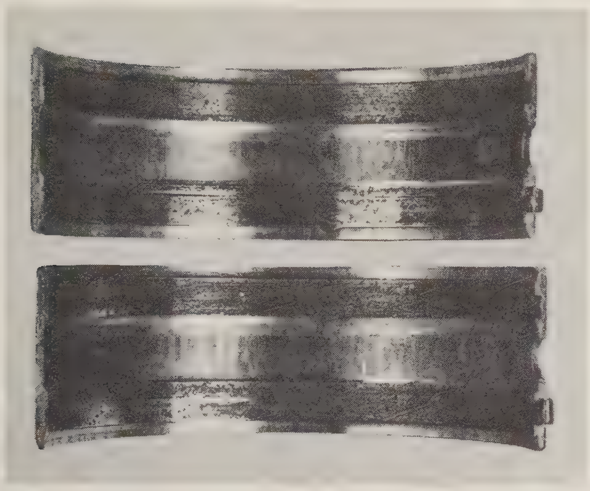


Fig. 3 (above left)—Moraine-400 V-8 engine rod bearings (⅝ in. long), with L/D ratio of 1 to 4, remain in good condition after 100-hour life test at 4,300 rpm.

Fig. 4 (above)—Production length bearings (⅞ in. long) after one-hundred hour test at 4,300 rpm.

Fig. 5 (left)—Grooves cut into bearing center resulted in effective L/D ratio of 1 to 10. Testing in this extreme form caused bearings to wear.

ving an L/D ratio of 1 to 4. These arings were in excellent condition after nning 100 hours at 4,300 rpm full rottle, which is considered a life test the production bearings having a ngth of ⅞ in. (Fig. 4). It was impossible reduce the length of this bearing rther without uncovering the crankpin hole. To avoid this, the standard ngth bearing was grooved in the center, ving a ¼ in. land at each end (Fig. This resulted in two bearing lands, ch having an L/D ratio of 1 to 10, and presents an area reduction of 43 per nt and a load increase of 75 per cent, th based on projected area. Although s difficult to determine the pressures posed on a bearing surface, in reduc- the bearing area by way of such surd L/D ratios, it is safe to say the ual pressure was increased in the ghborhood of 500 per cent. These arings still performed satisfactorily, but further reduction in bearing area resulted in a rapid increase in bearing wear and reduction in oil pressure. Although this gave definite evidence of loss of film lubrication, galling and scoring did not occur.

With the present trend toward increased horsepower, this bearing permits the designer to cope with the greater bearing loads which accompany the raising of the compression ratio and the enlarging of the piston size of an existing basic engine design. It is also possible for him to further reduce bearing lengths to allow him to increase the crankshaft cheek width to obtain the greater crankshaft rigidity required by greater torque.

In considering bearings of low L/D ratios, prevalent in current automotive engine designs, the bearing loading is increased approximately inversely as the square of the bearing length. A word of caution to be considered is that with the reduced bearing areas and increased unit bearing loads which these bearings will support, the oil film thickness is reduced. Unless extreme care is taken to control engine dirt, high bearing wear rate will ensue This presents the eternal engineering compromise to determine the point of diminishing returns.

Conclusions

On the basis of test results, it would seem that with this type of material, bearings are no longer a limiting factor in engine design. Moraine-400 bearings are completely interchangeable with babbitt lined bearings, and run equally well on oil hardened shafts.

As a result of these developments, production facilities have been provided for producing this material on a mass production basis, and this equipment is in the process of being installed and made ready for production at the present time.

A Discussion of 12-volt Automotive Electrical Systems

Six-volt electrical systems in modern automobiles fulfill most requirements entirely satisfactorily. However, some new automobiles with high-compression V-8 engines having overhead valves and larger carburetors and manifolds need the extra electrical pressure of a 12-volt system. The benefits include better ignition performance, higher generator output, faster cranking speeds, and a reserve for extra accessories.

The use of the 12-volt electrical system on passenger cars has been of technical interest for several years. During this time, several articles and comments have appeared in automotive periodicals outlining, in a general way, the advantages of the 12-volt system. The purposes of this paper are to show why more electrical performance is needed and to point out more specifically the design details that make it possible for the 12-volt system to supply this new performance level more easily. This treatment is intended to survey the problem, but the information presented is generally applicable to those 1953 General Motors car models which have 12-volt electrical systems.

There are three main reasons for making a change to the 12-volt system. These are the needs for (a) better ignition performance, (b) higher generator output, and (c) faster cranking speed.

Better Ignition Performance

Certain engines require higher voltages to produce the necessary sparking at the plugs. Primarily, the breakdown voltage of the spark plug gap is a function of the gas pressure around the plug at the time the spark occurs. This pressure has been increased throughout the speed range by higher compression ratios and further increased through the medium- and high-speed ranges by the better breathing of the engines.

There are a number of factors other than compression pressures that influence the breakdown voltage of the plug. Some of these are: fuel-air ratio; spark-plug gap length, and spark-plug electrode material, shape, temperature, and location in the combustion space. With so many variables, tests designed to show the effect of compression ratio have to be carefully controlled. Tests made on a single-cylinder, variable-ratio engine with plug gaps set at .040 in. indicate that there is a 10 per cent increase in breakdown voltage for each full ratio change in the range of compression ratios from 7:1 to 12:1. Other gaps show slightly different increases but the .040 in. gap was selected as being in the middle range for used spark plugs.

Several of the illustrations herein show curves of *voltage available* and *voltage required*. In order to define these terms, an explanation of the test procedure used to obtain the data is needed. The data for the voltage-available curves were obtained by connecting the input terminal of a cathode-ray oscilloscope to the secondary terminal of the ignition coil, then disconnecting the longest spark plug lead from the plug and observing the voltage developed on that lead under various operating conditions. The longest lead is selected since the higher electrostatic capacity of that lead gives it the lowest available voltage. At each operating condition the observer studies the pulses on the oscilloscope screen until he is reasonably sure that he has noted the lowest value of voltage that is likely to occur. The values shown by the curves are the lowest values that were observed. During low-speed operation there is considerable variation in the voltage available, often as much as 25 per cent. This spread decreases at higher speeds, and at top speed it is usually less than 10 per cent.

The voltage-required curves were obtained by looking for the highest value of voltage required to fire all of the plugs under various operating conditions. Observations were usually made at road load, full-throttle acceleration, part-throttle acceleration, and under surge or whip-driving conditions. Often the part-throttle acceleration or surge requirements are the highest, with maximum value occurring at the beginning of each acceleration. The voltage required under a given driving condition varies considerably, to the extent that the minimum value may be only 60 per cent of the maximum; so it is possible then to operate an engine with only occasional missing even though the plotted values of voltage required are higher than those of voltage available.

Fig. 1 illustrates how the ignition voltage requirements have increased during the period from 1946 to 1952. The engines from which these values were obtained were made by the same manufacturer. The 1946 engine was a production sample; the experimental engine was a recent development with high compression ratio and better breathing, but one that operated on present commercial fuels. The voltage was measured when the engines were equipped with plugs that had approximately 16,000 miles of use and gaps in the .034 in.-.040 in. range. It is not claimed that all of the increase was due to an increase in gas pressure. One test was made in 1946 and the other in 1952, and undoubtedly there were other uncontrolled factors which contributed to the difference. These results are typical of those found on other engines.

The bottom curve of Fig. 2 shows the voltage requirement of the experimental engine with new plugs gapped to the recommended setting. The top curve shows requirements after 16,000 miles of service. The increase in required voltage

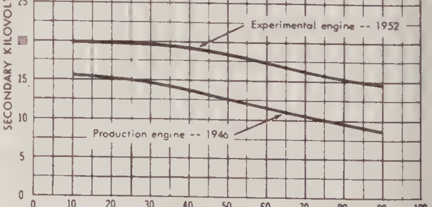


Fig. 1—Regardless of speed the modern engine requires higher ignition voltage than does 1946 production engine.

By HERMAN L. HARTZELL

Delco-Remy
Division

Higher battery E spells E-fficiency in some new cars

s shown by the upper curve is due to icreased gap length and to change in enter electrode shape, both caused by rosion. The voltage requirement cannot e reduced to the lower value just by egapping the plugs—change in the enter electrode shape makes this impos- ble. The middle curve shows the voltage at the 6-volt ignition system developed s applied to this engine. This test was nade with full electrical load (lights, eaters, and radio) and with high-limit etting of breaker points, in order to emonstrate the lowest legitimate output. is obvious that this engine will operate atisfactorily with the 6-volt system when e plugs are new, but that it will miss rohibitively throughout the speed range fter the plugs become deteriorated.

A brief review of the electrical charac- eristics of ignition systems will help to iow how the necessary higher voltages an be obtained. The ignition coil is a pe of pulse transformer. The energy andled is first stored in the magnetic stem as the current from the battery generator flows through the primary inding. The amount of energy stored is etermined by the inductance of the rimary winding and the amount of urrent flowing through it at the time e breaker contacts open; the relation energy stored is equal to $Li^2/2$ joules, here L is the primary inductance in enries and i is the primary current in nperes. When the breaker contacts parate, the energy is released quickly om the magnetic system and charges e capacities of the primary and the condary systems. The proportion of nergy going to each system is deter- ined by the relative capacities and ductances of each. The peak energy ansferred to the secondary is equal to $E^2/2$ joules, where C is the capacity of e secondary system in farads and E is e peak voltage in volts. This relation indicates that for a given energy transfer, a higher voltage can be obtained if the capacity of the secondary system is decreased. Consequently, several of the car manufacturers have arranged the secondary leads for minimum capacity to ground. This method alone does not provide sufficient voltage increase to take care of the experimental engine; so some method of increasing the energy input to the entire system must be used.

Since the energy input is $Li^2/2$, either L or i or both must be increased. The low-speed current that can be handled the required millions of times by the breaker contacts without their rapidly becoming oxidized must be held at, or below, the present level. Although the contacts used in the present system are made of the best material commercially available, they are barely able to handle the high currents which occur during cold-weather, slow-speed driving. Any increase would bring on an epidemic of complete ignition failures. Then, since the low-speed current cannot be in- creased, the only way to improve the low-speed performance appreciably is to raise the primary inductance.

As is generally known, the value of the primary current when the contacts open, often called current at break, decreases with increases in engine speed. The cur- rent, i, for any given time of contact closure can be determined by the relation

$$i = \frac{E}{R}\left(1 - \frac{1}{e^{\frac{Rt}{L}}}\right)$$

where E = supply voltage
R = total resistance in supply circuit
L = primary inductance in henries
e = 2.718 (natural logarithm base).

It should be emphasized that the total resistance R includes that of: the pri- mary winding of the coil, leads and harness, ignition switch, distributor leads and contacts, battery, and any other element which is in series with the coil primary (such as the resistor used with a 12-volt coil, described below).

At low speeds the quantity $1/e(Rt/L)$ is insignificant, and the primary current is approximately equal to E/R. With increased engine speed the quantity becomes greater, because t becomes smaller, and reaches a value of about 0.5 at top engine speed, thus reducing the current at break to about 50 per cent of the low-speed value. Any increase in L further decreases the current at break

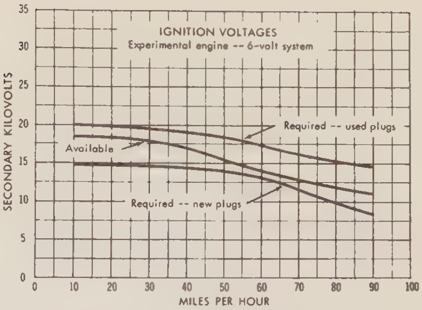


Fig. 2—After 16,000 miles ignition voltage avail- able is below the required level at all speeds for experimental engine with 6-volt electrical system. Erosion decreases spark plug efficiency.

at high speeds, hence, decreases the energy-input. However, the effect of an increase in L in the quantity $1/e(Rt/L)$ can be offset by an increase in either t or R. Factor t can be doubled by using the two-coil system wherein a four-lobe cam actuates two separate breakers, each controlling a separate ignition coil. R can be increased without decreasing the current at break, providing E is also increased such that the ratio E/R re- mains the same. It is apparent that doubling both E and R has the same effect as doubling t. Thus, the 12-volt system offers the same gain in ignition voltage output as the two-coil system. (The ignition problem in a 6-cylinder engine is not as acute as in an 8-cylinder because of the saturation time difference.)

The solid line of Fig. 3 shows the cur- rent at break for the 6-volt system with the maximum contact angle usable with an 8-lobe cam, after the system has reached a stable hot operating tempera- ture. The dashed curve shows current at break for the 2-coil, 6-volt system and the single-coil, 12-volt system when R is adjusted to give the same maximum hot current as the 6-volt, single-coil system, and when L has been increased 50 per cent. The increased current in the middle and upper speed ranges does not appre- ciably shorten contact life.

A 12-volt coil can be made in the same

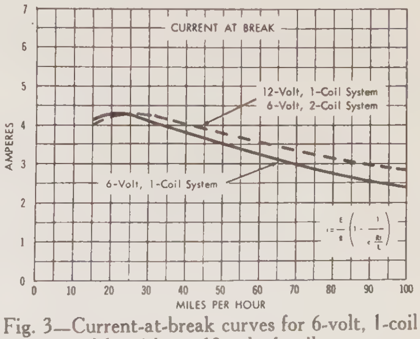


Fig. 3—Current-at-break curves for 6-volt, 1-coil system and for either a 12-volt, 1-coil system or a 6-volt, 2-coil system.

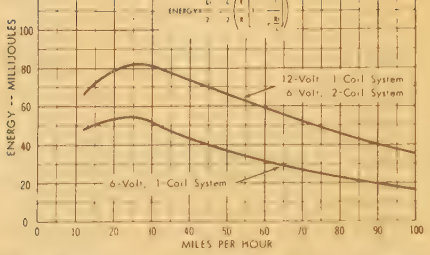


Fig. 4—6-volt, 1-coil system has the lesser energy input to coil at all speeds.

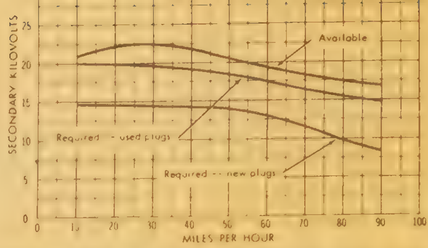


Fig. 5—With 12-volt electrical system plugs used 16,000 miles gave adequate ignition voltage.

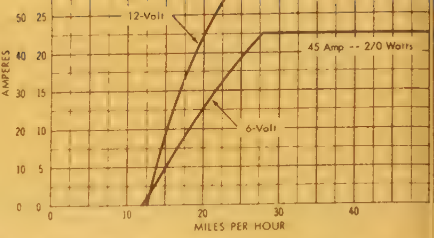


Fig. 6—12-volt system provides a 33 per cent gain in maximum generator power output.

size package as the 6-volt coil now used. With an external resistor made from constant-temperature-coefficient wire in series with the coil primary, less change occurs in primary resistance with variations in temperature; as a consequence, current at break is lower for the 12-volt coil when cold than for the present 6-volt coil. This characteristic decreases the tendency of the contacts to oxidize in cold weather when road conditions require slow driving. Thus an overall improvement in contact life could be expected with this arrangement.

Fig. 4 shows the equation for energy input to the ignition coil, also the increased energy input when the 12-volt, single-coil system or the 6-volt, 2-coil system is used. The increase at low speeds is the 50 per cent gained by using the larger value of L; the increase at top speed is 100 per cent, due to the increase in both L and i.

The 12-volt ignition system is preferred over the 6-volt, 2-coil system for three main reasons: first, when the two-coil system was used years ago the job of keeping the two breakers synchronized was never successfully accomplished, and with the present accent on timing accuracy the use of the dual breaker system would be a backward step; second, the added cost of the extra coil, dual breakers, double rotor, double cap, and double wiring makes the cost of the complete 6-volt electrical system thus modified about the same as that of a well designed 12-volt system; third, the 12-volt system makes it possible to obtain desirable performance gains in other components of the electrical system.

When a conservative design of the 12-volt ignition system is applied to the experimental engine of Fig. 1, the ignition voltage performance shown in Fig. 5 is obtained. Here the ignition system can handle the spark plugs which had 16,000 miles of use and gaps in the .034 in.—.040 in. range. Other tests on this system indicated sufficient reserve to handle these plugs even if gaps increased to .050 in.; this, coupled with the fact that normal gap growth is approximately .0008 in. per 1,000 miles, means that plugs could be used at least 25,000 miles before regapping would be necessary.

The voltage available from the 12-volt system can be further extended when the plug demands warrant making the required changes in application. Tests on 12:1 compression ratio engines show that sufficient voltage can be developed to handle used plugs with .040 in. gaps.

Both the 6- and 12-volt systems are vulnerable to extra losses in the ignition system such as caused by wet insulation, carbon-tracked distributor caps and rotors, and leaky cables. The more general use of good nipples on the plugs, caps, and coils; the use of distributor caps and rotors that can handle higher voltages; and the use of better cables can practically eliminate these sources of loss. The extra reserve of the 12-volt system will greatly decrease the number of ignition failures caused by lead and carbon fouled plugs. This gain coupled with the prospect of obtaining fuel additives that will decrease the amount of lead deposits may make this type of failure a very minor one.

There is a very good prospect, then, that the 12-volt system can allow the continued use of the simple, single-coil, single-breaker, easily maintained ignition system for many years, even though the trends toward higher-compression-ratio engines and better-breathing engines continue.

Higher Generator Output

When batteries were first put in cars to supply cranking energy, the 6-volt generators used to restore this energy had approximately 12 amperes capacity. As late as 1925, 15-ampere units were in general use. In present model cars current requirements are such that many standard equipment generators must produce 45 amperes output. This increase has been made in the same size package by means of forced ventilation, better-balanced design, and higher speeds provided by larger drive ratios. Further improvements in lighting and air conditioning and the use of electric windshield wipers and automatic dimming devices are pressing the demand for maximum output still higher. Also, the increasing magnitude of loads which may endure for long periods at slow speed is going to make it necessary to improve low-speed performance—either the efficiency of the present size generator must be increased, or a much larger unit will be required. Under-hood space limitations, as well as cost, make it desirable to maintain the present size, if at all possible.

It appears that just about the maximum is being obtained from the present 6-volt generator, but a change to 12 volts provides the needed improvement. As shown by the curves of Fig. 6, a 33 per cent gain in maximum watts output and much-improved, low-speed performance are both realized. A brief review of design characteristics peculiar to automotive generators indicates how changing to the higher voltage makes such improvement possible.

One limiting factor on automotive generator performance is the value of field current which can be handled by the regulator contacts. These contacts can handle about the same current at 12 volts as at 6 volts. To limit the field current to this value for 12-volt application means that generator field resistance must at least be doubled. To do this, smaller wire is used and more turns can be fitted into the space available for field windings. This means more ampere turns—as much as 25 to 30 per cent increase in field strength. This change increases heat losses in the field windings, but not enough to affect, materially, the overall generator temperature.

At first glance it would seem that the number of armature conductors should be doubled and the size of the conductors halved for 12-volt operation; actually, this is not the case. With the stronger fields and certain modification in the

roportions of the magnetic paths, it is ecessary to increase armature turns by nly 60 per cent to generate the desired oltage. This being the case, conductor ze can be greater than half that used for volts. Thus, armature current can be ore than half that of the 6-volt unit and aximum output *Ei* is greater.

There is marked improvement in the ope of the 12-volt curve, in the region f 15 to 25 mph, both because stronger elds reduce the effect of armature eaction and because the unit does not ave to generate so much useless voltage -another way of saying the efficiency is etter. At full output, a 6-volt machine ay have to generate 14 volts to get ven, while a 12-volt design would have generate only 21 to get 14.

The practical advantages of the 12-volt enerator are significant. For instance:

A 6-volt equipped 1952 car being driven in a city at night during cold weather has an electrical load of 43 amperes. The car speed has to be 27 mph in order for the generator to supply this load. A 12-volt equipped car driven under the same conditions has an electrical load of 23 amperes. The generator supplies this load at 20 mph. Obviously, under the conditions noted, especially when streets are covered with snow or ice, speeds near 20 mph are far more likely to be the general rule than speeds of 27 mph.

At speeds above those where full generator output is reached (6-volt, 28 mph—12-volt, 25 mph), after supplying the load, seven times as much energy is available from the 12-volt generator for storage in the battery than from the 6-volt—7 amperes at 12 volts vs. 2 amperes at 6 volts.

hen the change to 12 volts was desirable ot only from the standpoint of improved nition performance, but from that of nproved generator performance as well.

Faster Cranking Speed

More motor performance for cranking e larger engines at higher speeds is esirable for both cold and hot weather peration. Even though the owner follows e recommendations as to the proper l for cold weather operation, the 6-volt stem gives marginal performance at mperatures of —10 degrees F. and wer. A slightly higher cranking speed ill appreciably decrease the time required to start the engine. In hot weather, when there is a tendency towards vapor lock, a higher cranking speed will more quickly pump the vapor out of the system and thus assure much faster and more satisfactory starting. The 12-volt system properly designed provides the faster cranking under these two operating conditions.

It is even more desirable to maintain the present size of the cranking motor than of the generator: the problem of mounting a larger generator is primarily one of space, but that of mounting a larger cranking motor involves basic changes in engine blocks and fly-wheel housings, as well as space.

As in the case of the generator, the first impression might be that a 12-volt motor should have twice as many armature and field turns as a 6-volt motor. This, of course, would require that conductor area be reduced to one-half in order to maintain the same size motor. Such a design would have the same torque and speed characteristics as the present 6-volt motor, but it would not provide the needed improvement in performance. Furthermore, it would present numerous manufacturing difficulties and would cost considerably more. Accordingly, a compromise design seems the best solution, a design that would have fewer than double the number of turns. Of course, such a motor would draw more than half the current required by a 6-volt motor; consequently, in order to provide sufficient cranking time, it would be necessary to increase the wattage capacity of the battery.

The 6-volt battery now in general use with the larger 8-cylinder engines is the 17-plate type, rated 110 ampere-hours. Its equivalent in a 12-volt battery is a 9-plate, rated 55 ampere-hours. A 12-volt battery rated 70 ampere-hours comes in a case only slightly larger than the present 6-volt, 17-plate case—same length, ¼ in. less height, ¼ in. more width. The slight increase in size presents no particular problem as far as space is concerned.

The extra cost of this battery should not all be charged against the starting system—with its almost 30 per cent greater storage capacity, it better supplements the generator in carrying the cold-weather, slow-speed load without becoming discharged so quickly.

The faster cranking speed provided by a 12-volt motor and a higher wattage battery is shown by the curves of Fig. 7.

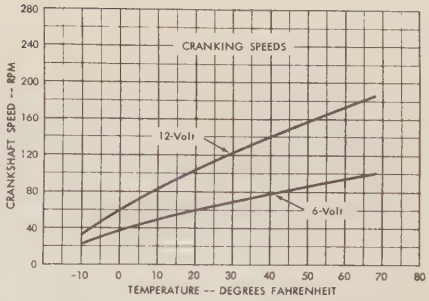


Fig. 7—12-volt system provides faster engine cranking speeds.

The motor must crank at a lower current because, although the storage capacity of the 12-volt battery is greater, the current capacity is less. This requirement can be fulfilled by making the fields stronger, by putting in more turns of smaller wire. This means more heat will be generated in the fields but, as in the case of the generator, the temperature still will not exceed a safe operating value.

To one not familiar with the electrical properties of cranking motors, the magnitude of the voltage (back emf) available for producing speed of rotation of the armature may appear ridiculously low. The reason, of course, is that the extremely high current involved causes high voltage drop in the battery, cable, and connections, and in the motor fields, armature, and brushes. In a 6-volt motor only 1.1 volts are available to produce speed of rotation of the armature. Even though the resistances of the wiring and the motor are higher in the 12-volt system, a back emf of 2.4 volts is available —this because of the higher initial voltage and the lower current. This more-than-doubled voltage available for producing speed of rotation of the armature almost doubles cranking speed of the motor—the increase, however, is not proportionate to the increase in back emf since the latter is somewhat countered by the increased flux supplied by the stronger fields.

Conclusion

To summarize, a 12-volt electrical system does fulfill the needs for: (a) better ignition performance, (b) higher generator output, and (c) faster cranking speed. It does so with the same distributor and with the same size coil, generator, and cranking motor. Battery size is increased by only 5 per cent, but energy storage capacity is increased by 30 per cent.

A Discussion of Cold-Working of Metals

Prepared by
Process Department,
Delco-Remy Division

A survey: from ancient coin-making to saving coin in industry today

Metals recrystallize with application of heat and may be formed in a molten state and, after cooling, are shaped by machining and other operations to conform to drawing specifications. Many shaping operations involving drawing, bending, or pressing may be done with metals at temperatures below their recrystallization points. These processes are called cold-forming, and new techniques in the art have resulted in material savings of up to 50 per cent and more over more conventional means in the manufacture of automotive-electrical and other parts.

New techniques in the cold-working of steel developed by the process engineers of the Delco-Remy Division have been successfully applied to the production of precision parts for many purposes. In certain applications, cold-working has proved to offer many advantages.

On the basis of Delco-Remy's experience with cold-working in the production of electrical equipment for the automotive industry over a period of many years, the Division can cite certain definite advantages for cold-working as compared to other methods of shaping metal parts in quantity. These advantages include:

(a) The process reduces waste, making possible material savings of 50 per cent or more on certain applications.

(b) It involves only standard presses and tools, thus eliminating the need for expensive special tools and lowering appreciably original costs of tooling up.

(c) It improves quality of product, for it lends itself to producing parts in quantity more accurately and uniformly than by machining methods.

(d) The process provides increased physical strength for parts when proper flow is maintained.

Thus, it can be stated that cold-working is not only a fast, efficient, and economical method of manufacturing, but it also produces parts which have superior physical and mechanical properties. And in an era when the conservation of materials is vital to the nation, the almost complete elimination of waste is a very attractive feature.

Fig. 1—Flat steel stock is welded into tubing (left). Five steps by the extrusion method follow and the part is ready for end-chamfering, keyway-punching, and other final operations.

The cold-forming process is an old art, but one which in recent years has been given new importance as new techniques have developed. The process can be defined as those operations which produce changes in the shape of a piece of metal by drawing, bending, or pressing at a temperature which is below the recrystallization point of a particular metal.

Processes utilizing the drawing and bending of metals are well known and are in wide usage on production parts of various shapes and contours. However, the pressing and forming of metals by compression, although well established for certain applications involving small parts of symmetrical shape, has not until recently been applied to precision steel parts of considerable size. Still another method known as gap rolling combines tension with shear rolling.

In order to get a complete picture of cold-working, it is well to review some of the history which has led up to and made these developments possible. The first known cold-working by compression was that of making coins. Some two-thousand years ago, man was using the principle of coining to make crude designs on precious metals. The tools in those days probably consisted of crude upper and lower dies. The metal was placed between the two halves and the upper was then struck with a sledge to form the coin.

Cold-working remained at the coin producing level until 1833, when the first knuckle-joint press was constructed for the French mint. That year may be

onsidered as the beginning of the nechanical age as far as cold-working f metals is concerned. The mechanical ress, along with advancements in netallurgy, has made possible the development of sizing, swaging, and extruding methods as used today.

About the turn of the 20th century, nother machine known as the cold eader came into use and this machine as permitted one or more of the cold-orming methods to be done in a single peration. Many of our common hardvare items such as bolts, nuts, screws, nd nails are now manufactured in this nanner. Delco-Remy uses cold headers o fashion small, high-production autonotive parts which were formerly made n screw machines. Considerable savings n labor and material have been made on uch parts as regulator cores and inserts or plastic molded parts. Through a ecent development, commutator bars re now made on a cold header, effecting substantial saving in copper.

A great demand for production and for onservation of materials during World Var II acted as an impetus for advancing he techniques of cold-working of metals, articularly steel. During the war period, Delco-Remy's intensive development program resulted in improved techniques n the art of cold-working which pernitted the application of this process to everal larger production parts. This evelopment program has been accelerted during the post-war period, and the pplication of cold-working to new omponents is under constant study.

Since at least 50 per cent of the nished cost of Delco-Remy products is n the cost of materials, the Division's ngineers and designers have of necessity ecome extremely waste-elimination conscious. Cold-working, with its tremenous potential for eliminating waste naterial, obviously provides a sound nswer for material savings without ompromising the quality of the product. n fact, experience has shown that the niformity and accuracy made possible y cold-working results in an improved roduct as well as in lowered costs.

During the past decade, Delco-Remy as adequately demonstrated the diverty of applications to which cold-working ends itself. In its production of electrical ystems for the automotive and allied ndustries, the Division lists as outanding examples of steel components abricated by cold-working, the following:

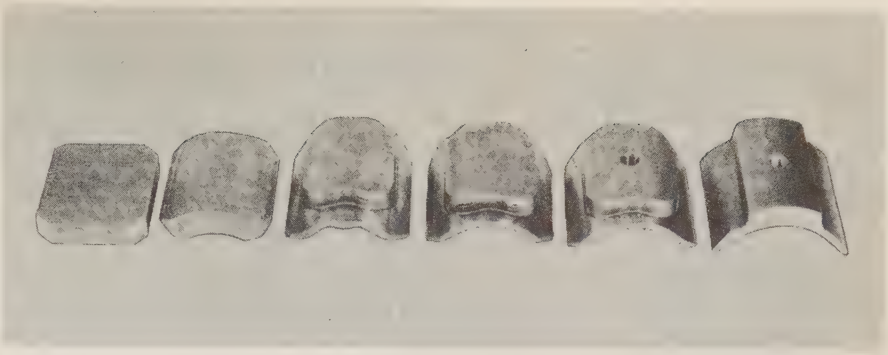


Fig. 2—Pole shoe is produced by swaging method from a flat, rectangular piece of steel. Final coining operations yield thickness tolerance of .002 in.

Extruding Method As Applied to Generator Shafts

Shafts for automotive-type generators are now made from flat steel stock which is first welded into steel tubing prior to extruding shoulders and various steps on both ends (Fig. 1). Simple operations of chamfering the ends, finish grinding the bearing ways, and punching the keyway are then performed and the shaft is ready for assembly. Material saving is 62 per cent over the old screw machine method in which the shaft was made from a solid bar of steel.

Swaging Method as Applied to the Fabrication of Pole Shoes

Pole shoes are now made from rectangular pieces of steel by first bending to fit the radius of the frame, then swaging the wings on all four sides, and finally coining the wings and body of the shoe to a thickness tolerance of .002 in. (Fig. 2). Formerly, these pole shoes were made from a special rolled section of steel purchased in long bars, cut to length, and then coined to thickness—the wings extending only on two sides.

The swaged shoe with its rounded corners permitted engineering changes which increased generator output and at the same time reduced the amount of copper required for field coils.

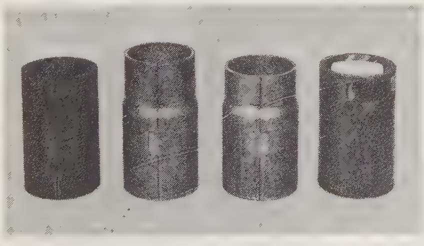


Fig. 3—Generator frame, largest part manufactured by a cold metal-moving process, begins with a low-carbon-plate steel which is rolled up to form a hollow cylinder. Extrusion and sizing operations follow.

Sizing and Extruding of Generator Frames

The generator frame is the largest production part ever manufactured at Delco-Remy by a cold metal-moving process (Fig. 3). This frame is made of low-carbon-plate steel which is rolled up to form a hollow cylinder $4\frac{9}{16}$ ins. in diameter and 7 ins. long. The cylinder is conditioned for further work and is then placed in a die which extrudes one end and sizes both the inside and outside diameters. The extruded end is reduced from $\frac{11}{32}$ in. to $\frac{3}{16}$ in. wall thickness, and the heavy section is increased .015 in. over the original $\frac{11}{32}$ in. wall thickness. In this manner, all the metal is *moved* and the entire frame is *sized.* (The excess material is cut off of the thin end and the frame is then ready for drilling.) Expensive welding, boring, and end facing operations which were necessary with the old straight-walled frame have been eliminated. Material savings amount to 20 per cent on each frame.

Conclusion

Cold-working is often said to be detrimental to the physical properties of the metal, but this is not so if proper flow is maintained. For instance, the high strength of music wire is obtained by proper cold-working. The strength is increased rather than decreased because only a small amount of metal is moved at any one time and the flow is not restricted. Parts produced in this manner have favorable characteristics equal to or better than those made by other known methods.

Although techniques have varied with each application, cold-forming has proved satisfactory and economical wherever adopted at Delco-Remy. Thus, another means has been made available for producing more with the same amount of human effort and material.

Chromium Plating of 90-Millimeter Gun Bores

Prepared by
Process Engineering Department,
Oldsmobile Division

Precision plated bores shoot straighter, last longer

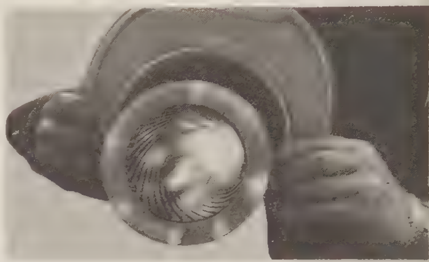
CHROMIUM plating of 90-millimeter cannon tube bores is now being performed on a mass production basis at Oldsmobile Division.

The cannon tubes are machined to the fine tolerances required, with allowances made for the electro-deposited thicknesses of metal desired. The tubes are then processed through the plating sequences, where a uniform deposit of chromium brings the bores to the finished dimensions specified. To achieve a plate that does not necessitate further machining or honing operations, strict adherence to the best practices must be made with close temperature and current controls maintained.

The plating installation and equipment features use of various metals and materials for specific purposes. Copper is used for high electrical conductivity with small cross section; aluminum for good conductivity and resistance to corrosion in the plating solution; steel for strength; tantalum in heat exchangers for corrosion resistance with good thermal conductivity, and plastics that are impervious to the solution for tank and valve linings. The solution is continuously filtered to remove particles in suspension that might interfere with a smooth deposit.

An interesting aspect of plating the inner walls of the tube is the current transferred by the solution. In usual decorative plating practices, a few amperes per gallon are passed through the solutions; while in the tube plating hundreds of amperes per gallon are used, due to the restricted volume inside the bores. The visible effect of these currents is a gushing of solution from the tube inches above the tube opening—a geysering action set in motion by entrained gases and electrically heated solution. Fortunately this phenomenon results in good solution circulation beneficial to the plated deposit.

A major problem met in plating



Chromium plating glistens from lands and grooves of 90-mm gun tube as employe gauges the outside diameter. Plating improves both wear resistance and gun's accuracy.

cannon tubes is the centering of the anode in the bore. In this process, the anode serves as one electrode in an electrolytic cell and the tube itself is the other, with but a fraction of an inch gap between the two for the 15 ft. length of the tube. If the tube is plated with the anode off-center, a deposit is obtained that is rough and unsatisfactory. The best solution to this problem has been a method of suspending the anode from the top of the gun, and letting its own weight aid in keeping it straight (Fig. 1). In a horizontal position and not properly supported, the anode would bend from its own weight. On the occasions when the anode must be moved to a horizontal position for repairs, it is supported its full length by a special fixture.

The physical dimensions involved in plating cannon tubes are emphasized by a 30-ft.-deep pit, a plated part weighing upwards of a ton, and the handling of plated parts and fixtures with bridge cranes.

The final result of the electro-plating process is a gleaming chromium surface that improves the wearing qualities of the rifled bore and increases the accuracy of the gun.

←

Fig. 1—A 15 ft. tube with the anode inserted is raised from subterranean plating bath after electrolytic process is completed. Plating cycle is completed in temperature-controlled bath.

Recently Developed Methods to Detect Defects in Forgings and Castings

By ROBERT M. BAKER
Cleveland Diesel
Engine Division

Heretofore costly and time consuming, the task of insuring perfect forgings and castings has recently been simplified by development of new processes and tools. One of the most recent uses ultrasonic waves to detect internal irregularities in a metallic structure.

Speed, consistency, reliability mark new flaw detection trend

THE DETECTION of defects in forgings and castings has in the past depended on such methods as magnetic particle inspection, x-ray, pressure test, various types of liquid penetrants, and visual inspection. Each of these methods has certain unfavorable elements, such as excessive cost; or the method may be too time consuming or lacking in sensitivity of detection.

These limitations have in recent years provoked efforts to develop improved methods. Several of these new methods are known as (a) liquid dye penetrant (Fig. 1), (b) fluorescent oil penetrant (Fig. 2), (c) fluorescent magnetic particle (Fig. 3), (d) two-vector magnetic particle, and (e) ultrasonic testing.

A number of liquid dye penetrant products are available on the market and all encompass the same principles for revealing defects. A highly penetrating colored liquid, generally red, is applied by dipping, spraying, or painting the cleaned surface of the parts. The liquid seeps into even the smallest defects in five or ten minutes. The part is washed with water or solvent to completely remove the penetrant from the surface. The part is then quickly dried and a developing solution applied. The latter is a solution of a white, chalk-like powder and a highly volatile vehicle such as acetone. The vehicle evaporates, leaving the white powder film which tends to draw the colored dye penetrant out of defects and serves as a contrasting background. The procedure takes only a few minutes and is very sensitive in detecting defects. The equipment is portable, permitting inspection of any area which can be seen and reached.

The fluorescent oil penetrant method employs an oil which is fluorescent under *black light* (near-ultraviolet). The cleaned part is either dipped, sprayed, or painted with the oil and allowed to drain for sufficient time to permit penetration of the oil into the defects. The oil is then rinsed from the surface of the part by either cold or hot water. After the part is completely dried, a liquid or powder developer is applied. In the case of the liquid developer, the substance, after drying, forms a powder film on the surface to draw the fluorescent oil from any defects. The part is inspected under a black light that causes the oil seeping from any defects to fluoresce. This method can be used on practically any type of metal and with good sensitivity in detecting surface defects. It is not as portable as the liquid dye penetrant method, since a source of black light is not always available. More time is required to complete this type of inspection than the liquid dye penetrant method, because of the additional draining and drying time.

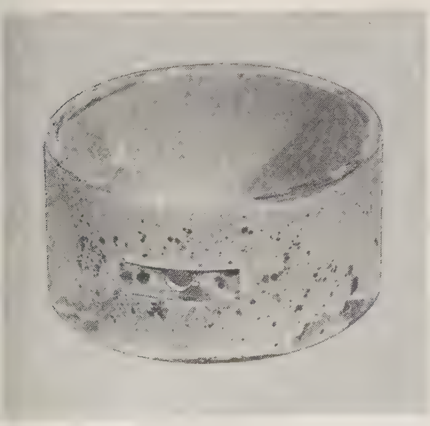


Fig. 1—Die penetrant seeps out of porosity to cause dark spots on cast bronze bushing. Method is considered rapid and detects minute defects.

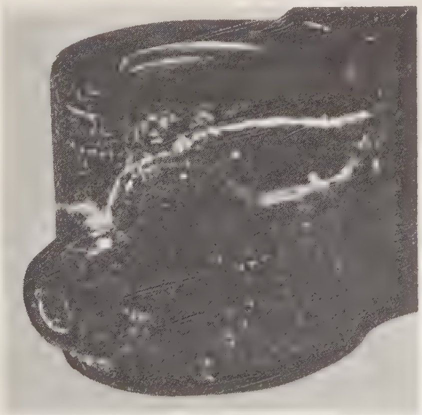


Fig. 2—Fluorescent penetrant oil seeps from crack in Diesel engine rocker lever tested after forging operation. Black light source is necessary.

Fig. 3—Fluorescent magnetic particle method discloses large crack in Diesel engine connecting rod. Method requires source of black light.

The fluorescent magnetic particle inspection is similar to the standard magnetic particle inspection, except that the finely divided magnetic particles fluoresce under black light and more clearly define the defects.

In both methods the part being inspected is magnetized in one direction only. The part is then covered with finely divided fluorescent magnetic particles suspended in non-fluorescent oil. These particles are held by the magnetic field, which occurs only at surface discontinuities or defects.

The two-vector magnetic particle method advances one step further than the fluorescent magnetic particle method, in that it enables parts to be inspected for surface defects in all directions in one operation. This is made possible by the use of a moving magnetic field that magnetizes the part in many directions without changing position of the part. Time is saved when parts must be inspected for defects in all directions. It is understood that this method has some limitations and is being used only in certain applications at the present time.

One of the latest and most interesting methods for locating internal defects in forgings and castings is ultrasonic testing. The equipment used in the test produces electrical impulses. These are converted into high frequency sound waves by a quartz crystal which is placed against the surface of the metallic part to be inspected. The sound waves, which are reflected back to the quartz crystal by the opposite surface (back reflection) and/or by any defects (if present), are converted back to electrical impulses. These impulses are shown as marks on a cathode-ray oscillograph as sound pattern.

Since the sound pattern markers indicate distance, the position of a defect can be located in the part being tested. To improve the transfer of the sound waves from the quartz crystal to the part, it is necessary to cover the surface of the part with oil. There are many variables in this method of testing, and each must be understood by the instrument operator. Interpretation of results is largely dependent upon previous experience and repetition of tests on the same parts. The method can be applied to most types of metal. When the procedure is mastered by the operator, it is a quick and sensitive method of locating internal defects in forgings, bars, sheet, and some castings (cast iron excepted).

A Typical Problem in Automotive Design

A common automotive design problem involves rods and piping. Piping is used in the hydraulic brake lines and fuel lines and ordinarily is shaped into a series of bends and radii to clear the parts around which it must pass. Rods must be designed to connect the accelerator pedal to the carburetor, the transmission to the bottom of the shift lever, the clutch pedal to the clutch. These rods too will have bends and radii to clear other working or stationary parts.

By GARRETT LOODE
staff,
General Motors
Institute

Shaped rods for mass production; determine pre-shaped length

The design engineer must, therefore, develop the shapes of these rods and piping and as a part of his specification he must indicate on the part drawing the true length of the pipe or rod before forming so cost estimates can be made and the pipe or rod cut to the proper length for the forming operations.

The determination of the true length of any pipe or rod he may design is a part of the work of the automotive engineer. Fig. 1 shows the two principal views of a transmission shift rod as they would be found on the part drawing.

Dimensions not essential to the solution have been eliminated. The problem is as follows:

> Determine the true length of the rod in Fig. 1 before it is bent into required shape. The solution should have graphical proof.

The answer to the problem will be published in the next issue of the GM Engineering Journal.

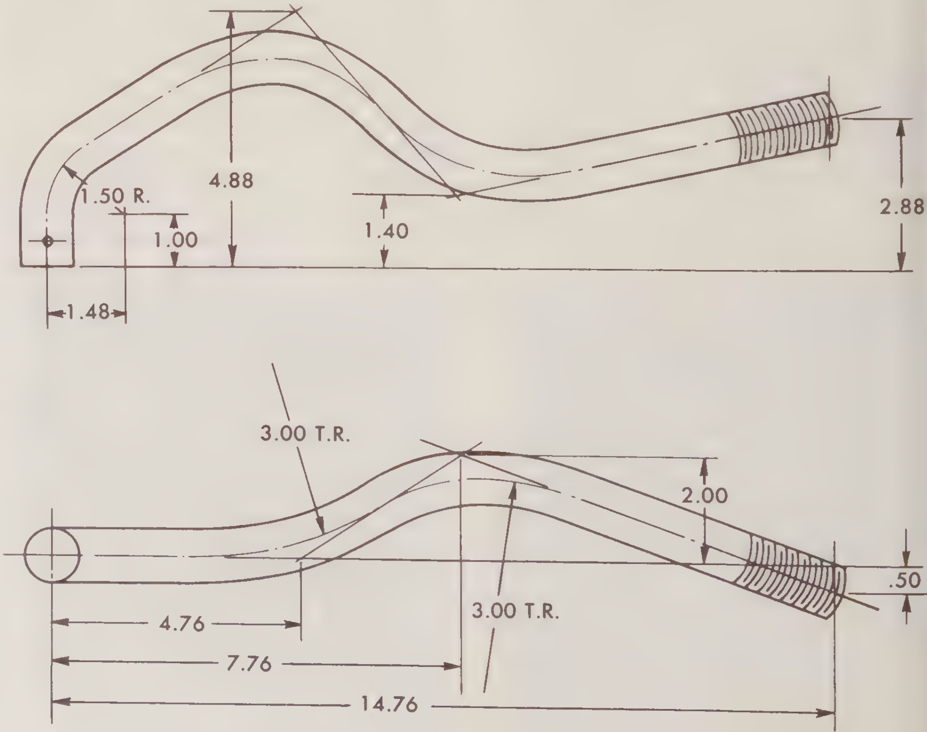


Fig. 1—Part drawing shows final shape and all dimensions essential to determine the true length.

Recent Speaking Engagements Filled by GM Engineers

General Motors' engineering messages reach the public by many means: radio and television, through the public print, automotive shows, exhibits at various conventions, open-house events, educator conferences, sound films, and the Parade of Progress which is now beginning an extended tour of the United States. In developing the GM Engineering Journal, which will be another way of sharing engineering information, the editors surveyed the technical staffs and operating units of General Motors to determine the magnitude of another outlet for information. With a reporting period designated from February 2 through March 13, the survey determined the number of engineers who appeared before an audience, usually in or near their own communities. Many Divisions responded that they sponsored appearances just before or just after, but the results nevertheless seem imposing. They are published below.

Three Allison Division engineers of Aircraft Engine Operations recently spoke before student chapters of A.S.M.E. on "The Current Status of Engineering Developments in the Field of Gas Turbine Engines for Aircraft." They were **J. R. Nelson**, senior project engineer on development of turbojet engine controls, at the University of Missouri on February 11; **R. M. Hazen**, director of engineering, at Purdue University on February 24, and **D. L. Bogue**, project engineer on turbine components, at Oklahoma A. & M. College on February 24.

Five Allison Division engineers of the Transmission Engineering Department, Transmission Operations, lectured before engineering students on "Torque Converters and Hydraulic Transmissions Used in Commercial and Ordnance Vehicles." Student A.S.M.E. audiences heard **Howard Christenson**, development engineer, at Notre Dame University on February 12; **R. M. Schaefer**, transmission engineering manager, at University of Colorado on February 16, and **J. A. Winter**, senior project engineer, at Georgia Institute of Technology on March 10. **J. E. Storer**, chief engineer, spoke before a joint S.A.E.-A.S.M.E. group at Carnegie Institute of Technology on February 26, and **E. M. Sharer**, chief test engineer, before engineering students at State University of Iowa on March 4.

Donald J. Nolan, assistant chief installation engineer, and **Vernon A. Ford**, test pilot, of Allison Division, presented a joint paper on "Progress Report of the Allison Turboliner" at the March meeting of the Indiana Section of the Society of Automotive Engineers.

Robert L. McWilliams, of the Educational Relations Section, Public Relations Department, Central Office, appeared before the Detroit Metropolitan parochial science teachers February 28 with the topic "Fundamentals of Ignition Systems and Automatic Transmissions." On February 21, Mr. McWilliams spoke on "The Expanding Opportunity in Engineering," in connection with the Work Shop on Guidance for High School Counselors of Southeastern Ontario. The work shop was held in St. Catharines.

S. E. Skinner, Vice President and Group Executive, spoke before the Texas Society of Professional Engineers at their Annual Dinner in Houston on February 26. His subject was "Dual Purpose Engineering."

Robert L. Kessler, Delco-Remy master mechanic, was a featured speaker at the 10th annual Machine Design Conference of the Cleveland, Ohio, engineering society in Cleveland Monday, February 2. His subject was "Method for Special Purpose Machines."

H. L. Hartzell, assistant chief engineer of Delco-Remy Division, spoke before the Mid-Michigan Section of the Society of Automotive Engineers in Owosso on

March 2. His paper "The 12-Volt Story" served as the basis of his talk.

Arthur Bender, quality engineer of Delco-Remy Division, spoke before the Muskegon, Michigan, Section of the American Society for Quality Control on February 17. His subject was "Fundamentals of Quality Control." On February 20 he spoke before the St. Louis A.S.Q.C. Section on "Military Sampling Plans."

John J. May, combustion engineer in the Engineering Laboratory of Detroit Diesel Engine Division, addressed the Smokemeter Group of the Coordinating Research Council on March 2 at the Detroit Diesel Plant. This group, which is sponsored by the Society of Automotive Engineers and comprised of members of the Diesel and oil industries, heard Mr. May speak on "Smokemeters."

Hans M. Gadebusch, fuels and lubricants engineer, and **John Dickson**, chief design engineer, both of the Engineering Department of Detroit Diesel Engine Division, spoke on March 11 before S.A.E. groups. Mr. Gadebusch addressed the Twin-Cities Section in Minneapolis on "Diesel Engine Operation at Subzero Temperatures," and Mr. Dickson addressed the Metropolitan Section in New York City on "General Motors Model 51 Diesel Engine."

Kenneth A. Stonex, head of the Technical Data Department, GM Proving Ground Section, addressed the Michigan Section of the Institute of Traffic Engineers at their meeting in Lansing on February 3. His topic was "The Relationship of Automobile Design and Traffic Problems."

J. R. Holmes, chief engineer at Harrison Radiator Division, spoke before S.A.E. members and guests in Detroit on March 5. His address was based on the Paper "Automobile Air Conditioning" by Mr. P. J. Kent, of Chrysler.

H. A. Reynolds, assistant chief product engineer in the Automotive Section, Engineering Department of Harrison Radiator Division, spoke before engineering students on "Cooling System Temperature Control." He appeared at the University of Pennsylvania on March 11 and at Pittsburgh University on March 12.

Louis C. Fisk, sales engineer in the Sales Department of Hyatt Bearings Division, spoke before the A.S.M.E. Student Chapter of Rutgers University on February 5. His subject was "Sales Engineering."

H. C. Schryver, senior engineer in Process Engineering, Packard Electric Division, spoke on February 12 before the Vocational Assembly at the local Warren G. Harding High School, Warren, Ohio. His topic was "Engineering as a Profession."

R. P. Koehring, chief metallurgist, and **Ross E. Kettering**, sales engineer, of Moraine Products Division, addressed a General Electric audience in Fort Wayne, Indiana, on February 26. Their subject was "Powder Metallurgy."

Nathan Weingarden, chief chassis draftsman, and **H. S. Kaiser**, chief body draftsman, both of the Engineering Department, Pontiac Motor Division, addressed members of the Department of Vocational Education and Practical Arts, University of Michigan, on January 24 at Milford. Mr. Weingarden's topic was "Lettering—An Important Part of Drafting Technique," and Mr. Kaiser's was "Drafting Personnel and Organization."

David M. Lee, mechanical engineer in the Plant Engineering Department of Oldsmobile Division, appeared before the Industrial Ventilation Conference at Michigan State College, held February 16-19. Mr. Lee was a group leader during the development of the afternoon laboratory problems.

E. D. Ditto, supervisor in the Methods Engineering Department, Oldsmobile Division, spoke before the Advanced Officers Training group at Aberdeen Proving Grounds on March 6. His topic was "Production Planning."

M. D. McCuen, Oldsmobile engineer, appeared before the Mid-Michigan Section of the Society of Automotive Engineers on March 2 at the Owosso, Michigan, City Club. His subject was "6- vs. 12-Volt Electrical Systems."

Contributors to June-July 1953 Issue of General Motors Engineering Journal

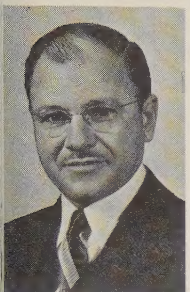
ROBERT M. BAKER, author of "Recently Developed Methods to Detect Defects in Forgings and Castings," is a metallurgist in the Metallurgical Department of Cleveland Diesel Engine Division, Cleveland, Ohio. He is primarily engaged in studies on reduction of alloy content of major engine parts. Mr. Baker joined Cleveland Diesel in February 1951, and was assigned to a special Navy engine program.

Mr. Baker received the B. S. degree in metallurgy from Case Institute of Technology in 1945. From May 1943 to March 1946 he served in the Naval Reserve as an engineering officer, attaining the rank of lieutenant, junior grade.

Mr. Baker was co-author of a previous paper, "Development of Residual Stresses in Strip Rolling," published by the American Institute of Metallurgical Engineers.

His technical affiliations include membership in the American Society for

Metals and the Society for Experimental Stress Analysis.



DARL F. CARIS,
co-author of "Engine-Transmission Relationship for Higher Efficiency," is head of the Automotive Engines Department, General Motors Research Laboratories, Detroit. He has, for a number of years, been engaged in the development of high-compression engines.

Mr. Caris began his engineering career in General Motors in 1926 as an electrical engineer in the Laboratories' Electrical Section. In 1931 he became a project engineer in the same department, specializing in development of instrumentation for measuring vibration, sound, acceleration, torque, and engine pressure. Mr. Caris was named head of Mechanical Engineering Department No. 4 in 1938, and in this capacity he was engaged primarily in research on internal combustion engine development, including two-cycle engines. During World War II he devoted his efforts to the development of gyroscope controls for Army Air Forces aircraft. The department's responsibilities have expanded with the Laboratories, and the name was recently changed to Automotive Engines.

The University of Michigan granted Mr. Caris the B. S. degree in electrical engineering in 1926 and in 1932 awarded him the professional degree of electrical engineer.

His several papers have dealt mainly with the development of high-compression engines. In 1947 he was co-author of a technical paper on this subject for the Society of Automotive Engineers. In 1948 he collaborated with two others on a study of thermal efficiencies of high-compression engines which was presented at an S.A.E. meeting in San Francisco. Mr. Caris, working with Dr. Edward J. Martin, head of GM Research Physics Instrumentation Department, developed technical papers on electrical engine indicators and other related subjects.

Patents in the oscillograph, engine blower control, and gyroscopic fields have resulted from his laboratory work.

Mr. Caris is a member of the American Physical Society, the Society of Automotive Engineers, and the Engineering Society of Detroit.

The paper published herein was presented with Mr. Richardson at the S.A.E. 1952 summer meeting in Atlantic City, New Jersey.

CHARLES A. CHAYNE,
author of "Responsibilities of General Motors Engineering in 1953," has served since January 1951 as vice president in charge of the engineering staff. His office directs engineering groups which perform engineering services for the benefit of General Motors as a whole. This work force, numbering about 1,800 engineering and technical personnel, is concentrated at the growing Technical Center, just north of Detroit. His office also coordinates the engineering efforts of more than one hundred distinct engineering organizations operating under Divisional managements.

Mr. Chayne joined Buick Motor Division in January 1930 and assumed charge of the engine division. He was appointed assistant chief engineer in 1933 and became chief engineer in 1936, which position he retained until becoming a corporation vice president.

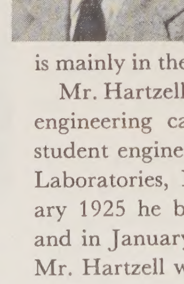
Notable successful developmental projects during Mr. Chayne's period at Buick included the straight-eight engine (predecessor of the present 90° V-8 engine), all-coil-spring suspension, automatic transmissions, and many other automotive advances. He was a leader in gaining national acceptance for E-Z Eye glass and the horn rim. His laboratory work resulted in eight patents covering steering linkages, spring suspension, frames, transmission controls, and valve mechanism temperature regulators. Other applications are pending.

Mr. Chayne started his career as a junior mechanical engineer in 1919 with the National Advisory Committee for Aeronautics. After one year in the NACA laboratories he became a mechanical engineering instructor at Massachusetts Institute of Technology for six years, then becoming an experimental engineer with the Lycoming Manufacturing Company. His first automotive engineering work was with the Marmon Automobile Company as a design engineer.

He earned the B.S.M.E. degree at M.I.T. in 1919. His society affiliations include the Society of Automotive Engineers and the American Society of Mechanical Engineers, and he recently was elected to Pi Tau Sigma, honorary engineering society.

JAMES H. GUYTON,
author of "Design Problems of Combination Signal Seeking and Push Button Radio Receivers," is assistant chief engineer, electrical, at Delco Radio Division in Kokomo, Indiana. Since March 1937, when he joined Delco Radio as a junior engineer, Mr. Guyton has devoted his efforts toward production problems and development projects on automobile radios and various electronic equipment for the armed services.

Washington University, in St. Louis, granted Mr. Guyton the B. S. degree in electrical engineering in 1934 and the M. S. degree, also in electrical engineering, in 1935. He was elected to Tau Beta Pi and the Society of the Sigma Xi. Prior to joining Delco Radio, Mr. Guyton was employed as a rural electrification survey engineer, and later was employed by the Sparks-Withington Company where he worked on household radio development.



HERMAN L. HARTZELL,
author of "A Discussion of 12-volt Automotive Electrical Systems," serves as an assistant chief engineer at Delco-Remy Division of General Motors Corporation, Anderson, Indiana, where his work is mainly in the field of his current paper.

Mr. Hartzell began his General Motors engineering career in June 1924 as a student engineer at Dayton Engineering Laboratories, Dayton, Ohio. In February 1925 he became a service engineer and in January 1926, a junior engineer. Mr. Hartzell was transferred in January 1927 to Delco-Remy Division as a product engineer. He rose to section engineer in July 1943, was promoted to staff engineer in April 1947, and was appointed to his present position in April 1950. Mr.

Hartzell's project work has centered around the study of ignition problems and the development of radio interference suppression equipment.

A 1924 graduate of Ohio State University, Mr. Hartzell received the bachelor of electrical engineering degree. He was elected to Eta Kappa Nu, Tau Beta Pi, and Pi Mu Epsilon honorary societies, and also won a major place on the varsity track team.

Mr. Hartzell's research in the field of automotive electrical equipment has resulted in 39 patents. His previous papers have included "Trends in Ignition Equipment," "Ignition Progress," and "Ignition Problems in Damp Weather."

A member of the Society of Automotive Engineers, Mr. Hartzell currently serves on the Ignition Research and the R.M.A.-S.A.E. Radio Noise Committees.

FORREST H. KANE, author of "Engineering Facilities and Product Development in a GM Division," serves as executive engineer of Pontiac Motor Division, which he joined in June 1912 when the organization was the Oakland Motor Car Company.

Mr. Kane has spent his entire career in automotive engineering, serving first with the Reliable Dayton Motor Car Company in Chicago in 1907 and 1908. He left to study mechanical engineering at Michigan State College, where he was elected to Tau Beta Pi honorary society and earned his degree just prior to joining Oakland. At Oakland he was promoted from draftsman successively to layout man and checker and during World War I represented the Company on the Automotive Industries Committee, in Washington. On his return he became chief draftsman and in 1920 joined the chief engineer's staff.

Mr. Kane's responsibilities as executive engineer have included liaison functions with the sales and advertising departments, the supervision of cost analyses and personnel. While his current manuscript was in preparation his major project was compilation of a report covering renegotiation of contracts for 1952.

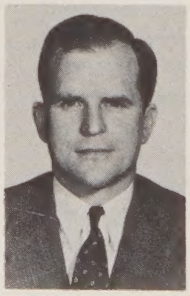
His work in the laboratories has resulted in a patent on an automotive cooling system. Mr. Kane is a long-time member of the Society of Automotive Engineers and of the Engineering Society of Detroit.

ELLSWORTH A. KEHOE, author of "The Men on the Boards," serves as administrative engineer at Rochester Products Division, where he was employed in 1940 upon earning the B.S.E.E. degree from the University of Alabama.

Mr. Kehoe began his career in the Rochester Products Post College Training Program. In 1941 he was appointed a supervisor of inspection and electrical testing on aircraft motors, motor-generators, dynamotors, alternators, and controls for alternators and generators. In 1945 he was transferred to the Engineering Department as a project engineer and participated in a program for the development of commutating brushes for high altitude operation.

Later in 1945, coincident with the Division's entrance into the manufacture of steel tubing, Mr. Kehoe was assigned to this project and served as their engineering representative to the various automotive and accessory Divisions. In 1949 he was assigned to the 4-jet carburetor development project, and in October of 1950 was promoted to his present position.

Mr. Kehoe is a member of the Rochester Engineering Society and while at the University of Alabama was elected to Tau Beta Pi.



WEBSTER J. OWEN, author of "Development of the Cadillac Air Conditioner," serves as an assistant staff engineer assigned to heating and air-conditioning projects in the Engineering Department of Cadillac Motor Car Division. His previous major projects have been on engine cooling, exhaust systems, and on armament for light tanks.

Mr. Owen's entire career has been with General Motors Corporation. While still a student at Beloit College, in Wisconsin, he was employed in April 1935 as an assembler in the Final Assembly Department of the Janesville Chevrolet Plant. Upon earning the B. S. degree in chemistry in June 1936, he joined Cadillac as a cooperative student. Upon completion of studies at General Motors Institute in 1938, he became a liaison engineer between the Cadillac Final Assembly and Engineering Departments.

In 1939, he joined the Technical Data Department, and two years later moved back to the laboratory benches as an assistant accessories engineer. Promotion to senior project engineer came in 1946, and subsequently Mr. Owen assumed project responsibility for engine cooling, exhaust and car heating and ventilating programs. He was appointed an assistant staff engineer in 1950. His work on heating and air conditioning has resulted in two patent applications.

Mr. Owen served in the Navy from June 1944 to April 1946, mainly as executive officer aboard motor torpedo boats. He was separated with the rank of lieutenant, junior grade. He is a member of the Society of Automotive Engineers.

O. LEROY PURTEE, author of "Balancing and Vibration Problems Related to Rotating Electrical Machinery," has served since July 1951 as head of the Metallurgical Section of the Engineering Department at Delco Products Division, Dayton, Ohio. He is currently engaged in the study of core loss in sheet silicon electrical materials used in motor production.

Mr. Purtee joined the Educational Department of Delco Products Division in August 1941 as a cooperative engineering student. He was transferred to the Engineering Laboratories in March 1949. Mr. Purtee received the bachelor of industrial engineering degree from General Motors Institute one year later, upon completion of a thesis bearing the same title as his current paper.

From April 1943 to May 1946 he served in the Navy, mainly as a motor machinist and as a yeoman. Mr. Purtee is affiliated with the American Society for Metals and the Engineers' Club of Dayton.

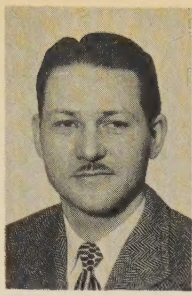
RALPH A. RICHARDSON, co-author of "Engine-Transmission Relationship for Higher Efficiency," is head of the Administrative Engineering Department in the GM Research Laboratories Division, Detroit. His department provides engineering service and correlates work of the Laboratories with engineering departments of the GM manufacturing Divisions and central staff operations.

Mr. Richardson was graduated from the University of Minnesota in 1927 with the B.S. degree in mechanical engineering. At this time he joined General Motors as a junior engineer at AC Spark Plug Division in Flint, Michigan, where he worked as a tool and die designer. In the fall of 1927 he was transferred to the Research Laboratories Division and assigned to the Technical Data Department. He became assistant department head in 1932 and four years later was named head of the department. The department recently was re-named the Administrative Engineering Department.

From January 1943 to January 1946 Mr. Richardson served in the Navy as a specialist electronics officer. He was assigned to the Bureau of Ordnance research and development section on fire control radar where he devoted his efforts primarily to training and operational research aboard combat ships. He was commissioned a lieutenant, senior grade, and attained the rank of lieutenant commander.

Mr. Richardson has been a frequent contributor to technical literature. A series of engineering booklets which he prepared for his department now are used in educational institutions, training courses, and engineering public relations activities. He contributed to the automotive section of Kent's Mechanical Engineering Handbook and was co-author of a book on the automotive industry published by the Encyclopaedia Britannica. He is currently engaged in the editorship of the forthcoming Automotive Engineers' Handbook.

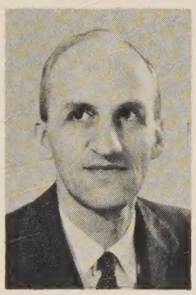
Mr. Richardson's technical affiliations include membership in the Society of Automotive Engineers and the Engineering Society of Detroit.



ARTHUR R. SHAW, author of "Properties and Production of Aluminum Bearings," has served since January 1951 as a bearing engineer in the Engineering Department of Moraine Products Division, Dayton, Ohio. He joined Moraine in June 1937 as a laboratory technician in the Engineering Department, and was promoted to mechanical engineer in 1942.

A 1937 graduate of Ohio State University, Mr. Shaw received the bachelor of mechanical engineering degree and was elected to Phi Eta Sigma and Tau Beta Pi honorary societies.

Mr. Shaw's work in powder metallurgy has resulted in four patents. He has written a previous paper on bearings which was published by the Society of Automotive Engineers, of which he is a member.



DR. ROBERT W. SMITH, author of "Emission Spectrographic Analysis in Industry," serves as senior engineer in charge of the Physics Research Laboratory at AC Spark Plug Division, Flint, Michigan, where he currently is primarily engaged in the development of new ceramic resistors for spark plugs and automotive instruments.

Dr. Smith joined AC Spark Plug as a senior project engineer in April 1935, after two years with the University of Michigan Engineering Research Department. At AC, Dr. Smith's work has included application of spectrographic analysis to materials control, development of glass sealing techniques for spark plug insulators, and development of physical testing methods for ceramic materials.

The University of Chattanooga granted Dr. Smith the B.S. degree in physics in 1929, and he earned the PhD degree, also in physics, from the University of Michigan in 1933. He was elected to Sigma Pi Sigma, Sigma Xi, and Blue Key honorary societies.

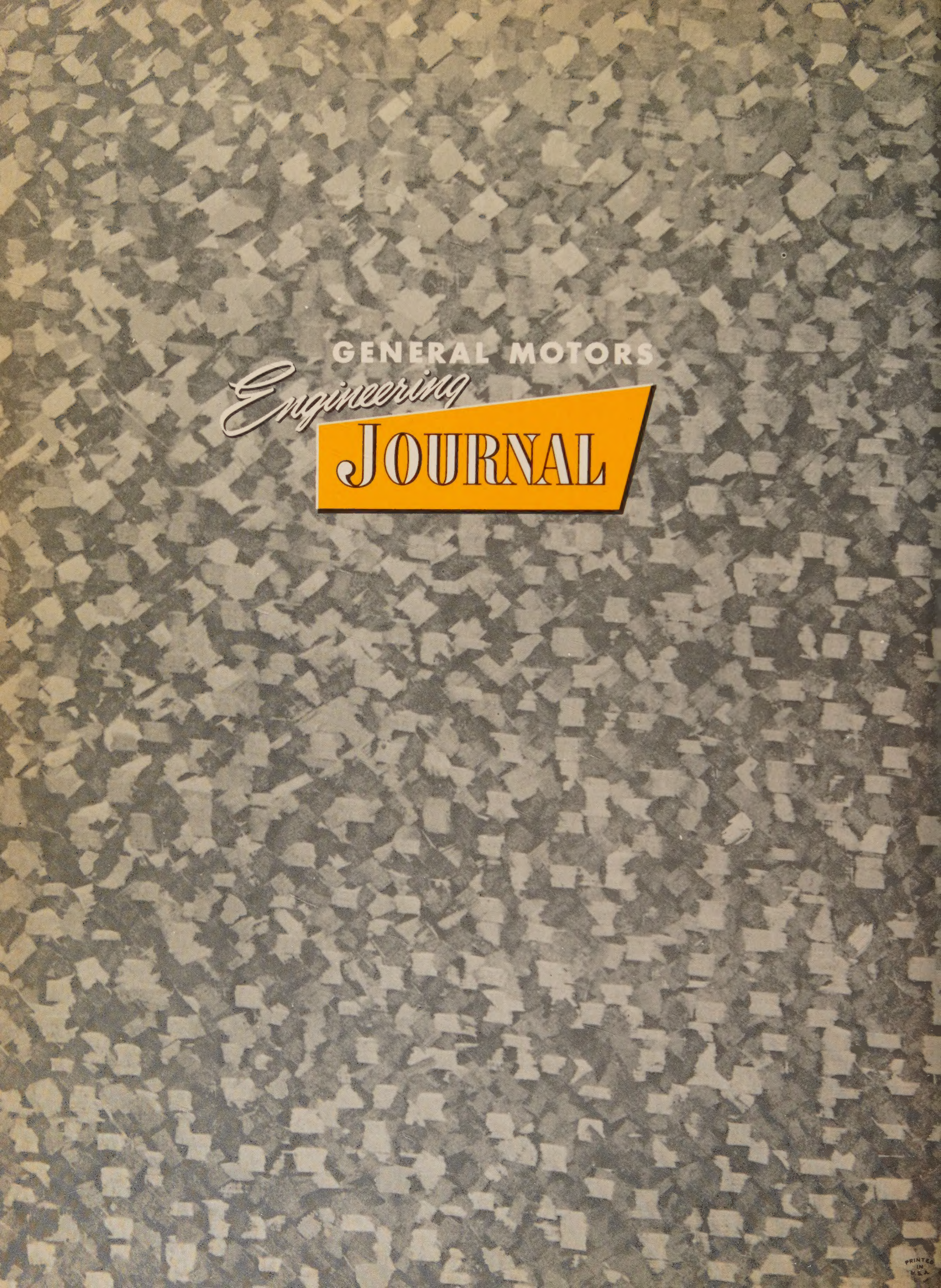
Dr. Smith's research in the field of spark plug and electrical instrument design has resulted in seven patents. He has been co-author of three previous papers on spectrographic analysis topics. His technical affiliations include membership in the American Society for Metals, American Institute of Electrical Engineers, Optical Society of America, American Association for the Advancement of Science, American Physical Society, and American Society for Testing Materials.

KENNETH A. STONEX, author of "Characteristics of the New GM Desert Proving Ground at Mesa, Arizona," serves as head of the Technical Data Department at the GM Proving Ground, Milford, Michigan, where he was originally employed in June 1933.

Mr. Stonex served first with Chevrolet Division at Milford and after leaving to earn a master's degree returned to Milford in his present department. In 1938 he became assistant head of the department and in June 1940, was appointed assistant head of the Mechanical Engineering Department. He became head of this department in March 1942 and continued as such through World War II when important testing of military equipment was conducted at Milford. He returned to his present department as its head in November 1945.

Mr. Stonex received the B.A. degree in mathematics in 1933 at Michigan State College, where he was elected to Phi Kappa Phi and Tau Sigma honorary societies. He also was awarded a State College Scholarship and attended University of Michigan, which awarded him the M.A. degree in mathematics in 1934.

He has been active in technical societies, with publications, and as a speaker on mathematical phases of automotive testing and testing facilities. His papers for delivery and publication by the Society of Automotive Engineers have included "Car Control Factors and Their Measurement" and "Passenger Car Wind and Roll Resistance." He is a member of both the Committee on Night Visibility and Geometric Highway Design on the Highway Research Board of the National Research Council. Mr. Stonex also serves on two General Motors technical subcommittees.


GENERAL MOTORS
Engineering
JOURNAL
PRINTED IN U.S.A.